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CONTENTS

	Page
The Influence of Thiouracil and Thiourea on the Growth and Fattening of Lambs, F. N. Andrews, W. M. Beeson, E. R. Barrick and Claude Harper	3
The Effect of Thiouracil in the Ration of Growing Swine, George W. Van Der Noot, Ralph P. Reece and William C. Skelley	12
The Effect of Thiouracil on the Growth and Fattening of Yearling Steers, W. M. Beeson, F. N. Andrews and P. T. Brown	16
Heat Tolerance Comparisons Between Jersey and Holstein Cows, D. M. Seath and G. D. Miller	24
Effects of Artificial Showers, Natural Rain and Wallowing on the Body Temperatures of Animals, F. C. Minett	35
Carotene Blood Levels and Reproductive Performance in Range Hereford Cattle, Merle G. Payne and H. E. Kingman	50
The Relative Accuracy of One-Day and Three-Day Weaning Weights of Calves, A. L. Baker, Ralph W. Phillips and W. H. Black	56
Effect of Techniques of Preparing Semen Smears for Staining on the Morphology of Bull Spermatozoa, Ernest Mercier and G. W. Salisbury	60
Refining Methods for Using Opal Blue Stain in Evaluating Ram Semen, L. O. Emik and G. M. Sidwell	67
Wool Fiber Density of Shropshire Lambs, John I. Hardy and Harold W. Wolf	72
Breed Crosses Used in the Development of Targhee Sheep, Clair E. Terrill	83
Record of Proceedings of the Thirty-Eighth Annual Meeting of the American Society of Animal Production	
President's Address	93
Summary of the Minutes of the Thirty-Eighth Annual Business Meeting	97
Memorials	102
Chairman of Committees and Sectional Meetings for 1947	103
Honor Guest, Henry P. Rusk	104
The Morrison Award, Jay L. Lush	106
News and Notes	108

Contents of previous issues of the JOURNAL OF ANIMAL SCIENCE are indexed in the Agricultural Index which is available in most libraries, and in the November issue of each complete volume of the JOURNAL.

THE INFLUENCE OF THIOURACIL AND THIOUREA ON THE GROWTH AND FATTENING OF LAMBS[1]

F. N. Andrews, W. M. Beeson, E. R. Barrick
and Claude Harper[2]
Purdue University Agricultural Experiment Station

THE role of the thyroid gland in the regulation of general body metabolism, metamorphosis, growth, and development is well known. The influence of the thyroid gland and its hormone, thyroxine, upon the amount and distribution of body fat is not thoroughly understood. Although obesity is frequently associated with hypothyroidism in the human, this is not always the case and some hypothyroid humans have very little subcutaneous fat. However, thyroidectomy, and the reduction of thyroid activity with thiouracil (Astwood, 1943; and others) is often followed by an increase in body weight in the human. Andrews and Bullard (1940) and Bullard and Andrews (1943) found that beef steers gained at an increased rate following partial thyroidectomy. The weight gains were markedly increased during the first six to eight postoperative weeks but were subsequently reduced to approximately preoperative levels following hypertrophy and hyperplasia of the thyroid gland remnants.

Richter and Clisby (1942), Kennedy (1942), Astwood and co-workers (1943) (1945), MacKenzie and MacKenzie (1943), and McGinty and Bywater (1945) have demonstrated that a large number of substances related to thiourea inhibit thyroxine secretion, decrease basal metabolic rate and result in thyroid hypertrophy and hyperplasia in the rat. Two of these effective compounds, thiourea and thiouracil, are available in quantities sufficient for large animal experimentation and were used in this investigation.

Turner *et al.* (1944) reported that thiourea and thiouracil will completely stop thyroxine secretion in cattle, sheep and goats when sufficient quantities of the drugs are fed. Kempster and Turner (1945) found that when New Hampshire chicks were fed a ration containing 0.2 percent thiouracil for a 16-day period beginning at 10 weeks of age, growth rate was unaffected but market grade was improved, and that when thiouracil was fed at this level for 36 days feed requirements per pound of gain were increased, growth rate was depressed, but market quality was greatly improved. Andrews and Schnetzler (1946) found that when thiouracil was fed at a level of 0.20 percent to Barred Plymouth Rock chickens between the 6th and 14th weeks growth was slightly retarded but market grade and fat deposition

[1] Contribution from the Department of Animal Husbandry, Journal Paper No. 261, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

[2] The authors are grateful to Eli Lilly and Company for the thiouracil and thiourea used in this study and to Dr. K. K. Chen of the Lilly Research Laboratories for his interest and advice in the conduct of the research.

were significantly increased. Although the treated birds made less gain, their efficiency of feed utilization was greater when adjusted for gain.

Muhrer and Hogan (1945) reported that the addition of thiouracil to the ration of fattening swine reduced feed intake, but increased fat deposition and the efficiency of feed utilization.

Materials and Methods

Texas feeder lambs of predominately Rambouillet breeding, approximately seven months of age and averaging 74 pounds in weight were used in this study. Eight lots of 20 lambs each were selected on the basis of body weight and general similarity and fed from December 12, 1945, until March 6, 1946, a period of 84 days.

All lots received a basal ration of No. 2 shelled yellow corn, well matured corn silage, average quality red clover hay containing some mixed grasses, loose salt, and a pelleted protein concentrate made up of equal parts of expeller process soybean oil meal and good quality alfalfa meal and two percent salt. Preliminary experiments had shown that sheep did not readily consume feeds mixed with bitter tasting thiouracil and it was thought that if the drugs were incorporated in a pelleted protein concentrate it might be possible to mask their taste somewhat.

It was hoped that feed consumption could be fairly evenly maintained in all lots and that all lambs would eat 0.4 of a pound of pellets daily. Thiouracil and thiourea were incorporated in the pellets in quantities that would provide 0.25 gm., 0.50 gm., 1.0 gm., and 2.0 gm. of thiouracil per lamb daily in lots II, III, IV, and V respectively, and 0.25 gm., 0.50 gm. and 1.0 gm. of thiourea per lamb daily in lots VI, VII, and VIII respectively, if 0.4 pound were eaten daily. However, it was not possible to maintain the planned thiouracil and thiourea intakes and the actual daily consumption of these drugs is shown by lots in table 1. On January 5 the free choice loose salt was removed from all except the control lot in hope that pellet consumption would be increased as the sheep became salt hungry (the pellets contained two percent salt). Loose salt was returned to lots VII and VIII on January 21 and to lot VI on February 8. In lot V an attempt to increase thiouracil intake was made by grinding corn and pellets together in a hammer mill. The ratio of corn to pellets was 1:0.4 from January 3 until January 23 and was changed to 1:0.3 from January 23 until the termination of the experiment.

The lambs were weighed individually on three consecutive days at the beginning and close of the experiment, and at four-week intervals during the trial. Lot weights were taken every two weeks. The dressed weights were obtained at the time of slaughter and the carcasses were officially graded according to federal standards.

TABLE 1. EFFECT OF THIOURACIL AND THIOUREA ON THE GROWTH RATE, FEED CONSUMPTION AND FEED EFFICIENCY OF LAMBS
(Feeding period, 84 days)

Items compared \ Lot no. and ration	I Basal ration	II Basal ration +0.18 gm. thiouracil daily	III Basal ration +0.33 gm. thiouracil daily	IV Basal ration +0.54 gm. thiouracil daily	V Basal ration +1.15 gm. thiouracil daily	VI Basal ration +0.07 gm. thiourea daily	VII Basal ration +0.05 gm. thiourea daily	VIII Basal ration +0.06 gm. thiourea daily
Number of lambs	20	20	20	20	20	20	20	20[1]
Growth Rate								
Av. initial wt., lb.	74.75	73.90	73.90	74.45	74.65	72.85	74.85	75.11
Av. final wt., lb.	101.95	99.85	100.80	98.65	96.90	96.10	97.40	95.11
Gain per lamb,[2] lb.	27.20	25.95	26.90	24.20	22.25	21.25	22.55	20.00
Daily gain per lamb, lb.	0.32	0.31	0.32	0.29	0.26	0.25	0.27	0.24
Daily Feed Consumption per Lamb								
Yellow corn, lb.	0.92	0.92	0.92	0.92	0.80	0.92	0.92	0.93
Pellets, lb.	0.34	0.28	0.27	0.22	0.23	0.12	0.04	0.02
Red clover-timothy hay, lb.	1.11	1.08	1.14	1.15	1.16	1.17	1.19	1.30
Corn silage, lb.	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.92
Salt, lb.	0.012	0.008	0.008	0.007	0.007	0.008	0.010	0.011
Thiouracil, gm.	0.000	0.175	0.333	0.544	1.148	—	—	—
Thiourea, gm.	—	—	—	—	—	0.071	0.048	0.064
Total, lb.	3.352	3.258	3.308	3.267	3.167	3.188	3.130	3.181
Feed per Pound of Gain								
Yellow corn, lb.	2.85	2.98	2.88	3.20	3.03	3.64	3.44	3.92
Pellets, lb.	1.05	0.91	0.83	0.76	0.86	0.45	0.14	0.11
Red clover-timothy hay, lb.	3.44	3.51	3.57	3.99	4.33	4.63	4.43	5.46
Corn silage, lb.	2.99	3.14	3.03	3.36	3.65	3.83	3.61	3.88
Salt, lb.	0.038	0.025	0.024	0.023	0.028	0.033	0.037	0.047
Total, lb.	10.368	10.565	10.334	11.333	11.963	12.583	11.657	13.417

[1] Two lambs died in this lot.

[2] The least significant differences for gain in weight are 3.8 pounds at the 5% level and 5.0 pounds at the 1% level.

The thyroid glands were removed from ten lambs selected from each lot at random at the time of slaughter, gross weights were obtained and tissues were prepared for microscopic examination.

The data were treated statistically by the method of analysis of variance as outlined by Snedecor (1946).

Results

Growth Rate

The data summarizing the effects of thiouracil and thiourea on growth rate are presented in table 1. The addition of thiouracil to the ration at

levels of 0.175 gm. to 0.544 gm. per lamb per day had no significant effect on rate of growth as measured by total gain in weight, although rate of gain was slightly less in all lots receiving thiouracil. When thiouracil was fed at the rate of 1.148 gm. per lamb daily the gain was significantly decreased ($P < 0.05$). Thiourea produced highly significant reductions in rate of gain when fed at levels of 0.064 and 0.071 gm. per lamb per day ($P < 0.01$) and a significant depression of gain when the intake was 0.048 gm. per day ($P < 0.05$).

Feed Consumption

Although it was hoped that the feed intake of all lots could be equalized, it was not intended that the total feed consumption of the control lambs would be limited to that of the group consuming the smallest quantities of feed. As shown in table 1, the hay and silage intake was nearly identical in all lots, and with the exception of lot V, in which the corn was ground with the thiouracil-containing pellets, corn consumption was equalized. It was intended that all lots would receive 0.4 of a pound of pellets per lamb daily in order that the calculated amounts of thiouracil and thiourea would be consumed. However, pellet intake decreased as thiouracil content increased and in the thiourea lots the pellets were consistently rejected and were nearly completely refused in lot VIII. When it became apparent that pellet consumption could not be increased in this lot hay intake was somewhat increased. There were no marked differences in total feed consumption between any of the lots but feed intake was somewhat reduced in all of the groups receiving drugs. Individual lambs in lot VIII frequently refused nearly all feed and some individuals apparently did not eat any pellets during the latter part of the feeding period.

Feed Efficiency

There were no differences in total feed consumption per pound of gain between Lots I, II and III but there was a distinct tendency for the amount of feed required per pound of gain to increase as the levels of thiouracil and thiourea increased. Some of this difference can probably be explained on the basis of a decreased rate of growth in the lambs receiving the drugs and some of the difference is undoubtedly due to the lowered protein intake which resulted from decreased pellet consumption.

Thyroid Changes

Both thiouracil and thiourea have a direct effect upon the size, microscopic anatomy and function of the thyroid gland. The influence of these drugs upon the histology of the thyroid will be discussed in a subsequent paper but the effects upon thyroid weight are summarized in table 2.

Thiouracil and thiourea, at all levels fed, produced highly significant increases in thyroid weight ($P < 0.01$). There were no significant differences between the thyroid weights of lots II, III and IV. In lot V, when the thiouracil pellets were ground with the corn, thyroid size was less than for any of the other thiouracil lots and smaller than expected on the basis of calculated thiouracil intake. However, it is possible that some thiouracil may have sifted out of the corn-pellet mixture, that its biological effect may have

TABLE 2. EFFECT OF THIOURACIL AND THIOUREA ON THYROID WEIGHT, CARCASS YIELD, AND CARCASS GRADES OF LAMBS

Items compared \ Lot no. and ration	I Basal ration	II Basal ration +0.18 gm. thiouracil daily	III Basal ration +0.33 gm. thiouracil daily	IV Basal ration +0.54 gm. thiouracil daily	V Basal ration +1.15 gm. thiouracil daily	VI Basal ration +0.07 gm. thiourea daily	VII Basal ration +0.05 gm. thiourea daily	VIII Basal ration +0.06 gm. thiourea daily
Average thyroid weight,[1] grams	2.30	12.18	10.53	13.58	9.78	7.56	11.93	14.60
Yield, in percent	46.05	46.50	46.15	46.55	45.69	46.00	45.23	46.10
Carcass grades, percents in each grade								
AA	35	55	60	45	21	10	0	17
A	60	45	40	40	68	80	75	78
B	5	0	0	15	10	5	25	5
C	0	0	0	0	0	5	0	0
Numerical index value[1,2]	1.70	1.45	1.40	1.70	1.90	2.05	2.25	1.90

[1] Least significant differences at the 0.05 and 0.01 levels, respectively, were 3.77 and 5.01 grams for thyroid weight, and 0.35 and 0.46 (numerical index value) for carcass grade.

[2] Obtained by assigning a value of 1 for each AA, 2 for A, 3 for B, and 4 for C.

been somewhat affected by the physical nature of the mixture, or that the grinding of corn and pellets may have facilitated the sorting of the coarsely ground corn from the drug by the sheep.

There were significant thyroid weight differences between the lambs in some of the thiouracil and thiourea lots and between the various thiourea groups. It is interesting to observe, however, that although the lambs in lot VIII consumed an average of 0.064 gm. of thiourea per day for the entire experimental period their thyroids were highly significantly heavier than those of the sheep in lot VI ($P < 0.01$). The possible causes of this fact fall in the realm of speculation and will be discussed elsewhere, but the experiment was designed with the intent that the animals in lot VIII would receive pellets containing four times as much thiourea as the sheep in lot VI. It seems possible that changes in thyroid function initiated in the early days of the experiment progressed to completion even after thiourea was voluntarily limited by the lambs.

Carcass Studies

There were no lot differences in dressing percentage (table 2). The distribution of official federal carcass grades of the lots are summarized in table 2. The grades were assigned the following numerical values and an analysis of variance performed: AA = 1; A = 2; B = 3 and C = 4. Although numerous objections can be raised to the arbitrary subsitution of numerical values for alphabetical official (but relative) grades, it should be pointed out that there is probably a relatively greater difference between grades AA and A, than between A and B, and that a statistical analysis of the type performed is probably on the conservative side. The data show that carcass quality was improved in lots II and III and approached significance ($P > 0.05$). There were observable increases in cod fat and in internal fat in lots II and III but no quantitative measurements were made. Carcass quality in lots VI and VII was significantly less than in the controls and highly significantly less than in lots II and III.

Discussion

Thiouracil at certain levels has been shown to inhibit growth rate consistently. Astwood *et al.* (1944) showed that when thiouracil was added to the feed of newly hatched chicks at a level of 0.5 percent, growth was markedly retarded. When thiouracil was fed to pregnant or suckling rats and/or their young, growth was retarded and changes similar to those seen in cretinism were produced (Astwood, 1943; Hughes, 1944; Goldsmith *et al.*, 1945). Kempster and Turner (1945) found that when thiouracil was added to chick rations at a level of 0.20 percent beginning at the 8th week of age, growth rate was depressed. Andrews and Schnetzler (1946) reported that, although the addition of thiouracil at levels varying from 0.025 to 0.20 percent tended to reduce growth, the depression in rate of gain was not statistically significant in females but was highly significant in males (0.20 percent thiouracil) if artificial illumination was provided for a brief period during the night. These effects were not observed in males receiving 0.20 percent thiouracil in the ration when light was not provided, and the results were attributed to increased drug intake made possible by the additional feeding period.

Muhrer and Hogan (1945) reported that when thiouracil was added to a swine ration at a level of 0.20 percent and hand fed, the rate of gain of the groups receiving the drug was highly significantly greater than in the controls. However, it has been observed by the authors that swine, sheep and cattle apparently object to the taste of thiouracil and thiourea and their food intake is curbed by feeds containing these drugs. Muhrer and Hogan

(1945) limited the feed intake of the control swine to the levels of the thiouracil fed groups. Under these conditions of restricted feeding the rate of gain of the controls was markedly inhibited and as pointed out by the investigators the control animals would have consumed more feed by ad libitum feeding and would have gained more rapidly.

As previously discussed the addition of thiouracil and thiourea to the rations of fattening lambs decreased the rate of gain at even the lowest level of drug intake. However, no significant decrease in gain was obtained until thiouracil was fed at a rate of 1.148 gm. per lamb daily. Thiourea had more effect upon rate of gain than thiouracil and produced a significant depression when the intake was as low as 0.048 gm. per lamb daily. Since thyroid secretion is necessary for normal growth and development, it would be expected that an inhibition of thyroid secretion would depress growth.

One of the limiting factors in the practical use of thyroid inhibiting agents is their palatability to farm animsls. Chickens apparently are unable to detect the presence of thiouracil at even relatively high levels and as shown by Andrews and Schnetzler (1946) feed intake was not reduced in chickens receiving this drug. Considerable difficulty was experienced in getting lambs to eat such common feeds as cottonseed meal, soybean oil meal, wet beet pulp and ground corn when mixed with thiouracil. Further work showed that the addition of salt to such feeds tended to mask the taste of thiouracil even more effectively than the use of substances such as saccharine. For these reasons it was decided to incorporate the drugs in a pellet consisting of soybean oil, alfalfa meal and salt. As previously pointed out, planned pellet consumption could not be maintained and it is not felt that the palatability problem has as yet been solved. Observations tended to indicate that the removal of other sources of salt from the lambs increased the intake of the pellets, presumably because the lambs were forced to depend on the pellets as their only source of salt.

There were no detectable differences in the efficiency of feed utilization in the lambs receiving up to 0.33 gm. of thiouracil per day, and a distinct tendency for increased feed requirements per pound of gain in the lots receiving thiourea and the higher levels of thiouracil. This is in contrast with the findings of Andrews and Schnetzler (1946) that in both male and female chickens fed 0.20 percent thiouracil the efficiency of feed utilization was greater when adjusted for gain by the analysis of convariance. Kempster and Turner (1945) however, although they did not adjust for gain, reported that the feed requirements per pound of gain were increased in chickens when thiouracil was fed for 36 days. When feed intake of normal swine was limited to that of animals receiving thiouracil, Muhrer and Hogan (1945) observed a highly significant increase in the efficiency of feed utilization. This

has not been observed in experiments at this station with swine when all groups were fed ad libitum.

The response of the thyroid as measured by weight was highly significant for both thiouracil and thiourea at all levels fed to lambs. In chickens thiouracil at a 0.20 percent level increased thyroid weight approximately 20 times and, in one extreme case, 70 times normal (Andrews and Schnetzler, 1946). In lambs the average thyroid weight was increased approximately 5 times and in one isolated case 16 times. However, if the thiouracil intake were calculated on a percentage basis it would range between 0.01 and 0.08 percent of total food intake and the percentage of thiourea in the rations was considerably lower (actually 0.0033 percent in lot VII). It would appear that both thiourea and thiouracil are highly effective in inhibiting thyroid function in sheep.

When thiouracil was fed at the rate of 0.175 and 0.333 grams per lamb daily, carcass quality was considerably improved. Fifty-five and sixty percent of the carcasses in these respective lots received the top market grade (AA), in contrast with 35 percent AA lambs in the controls. Although fat determinations of the entire carcass were not made, it was apparent that cod and internal fat deposition were increased. It has been shown in chickens that cutaneous fat was increased 8 to 9 percent and that market quality was significantly improved ($P < .01$) by the addition of thiouracil to broiler rations (Andrews and Schnetzler, 1946). The results with both chickens and lambs suggest that the production of experimental hypothyroidism decreases the metabolic rate and thus results in decreased energy requirements for maintenance. This in turn would allow a larger proportion of the ingested nutrients to be converted into fat on the same food intake.

Summary

Thiouracil intakes of 0.175 gm. to 0.544 gm. per lamb per day had no significant effect on the rate of growth as measured by total gain in weight, although rate of gain was slightly reduced in all lots receiving thiouracil.

Thiourea produced significant reductions in lamb growth when fed at levels ranging from 0.048 to 0.071 gm. per lamb daily.

Feed intake was somewhat reduced in all the groups receiving thiouracil and thiourea. Neither thiouracil nor thiourea was relished by lambs and both were definitely unpalatable.

The feed requirements per pound of gain were not affected by thiouracil until intake exceeded 0.333 gm. daily but there was a tendency for the gross efficiency to be reduced as the levels of thiouracil and thiourea were increased.

Thiouracil and thiourea at all levels fed produced highly significant increases in thyroid weight.

The largest numbers of top grade (AA) carcasses occurred in the lots receiving 0.175 and 0.333 gm. of thiouracil per lamb daily. These lot differences approached statistical significance.

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THE EFFECT OF THIOURACIL IN THE RATION OF GROWING SWINE[1]

GEORGE W. VAN DER NOOT, RALPH P. REECE AND WILLIAM C. SKELLEY

New Jersey Agricultural Experiment Station

WITH the establishment of the physiological action of thyroxine, considerable attention has been given, in recent years, to the role of the thyroid gland in the growth, fattening, and milk secretion processes of animals. Reece and Turner (1937) have reported a greater concentration of the thyrotrophic hormone in pituitaries from dairy cows than in those from beef cows. They suggested that the ability of the pituitary glands of these two cattle types to secrete the thyrotrophic hormone may consitute one of their major differences. Since a hypothyroid condition is usually associated with a tendency to fatten, several investigators have determined the influence of inducing such a condition in meat producing animals. Andrews and Bullard (1940) observed a rapid fattening and gain in weight in steers following partial thyroidectomy.

Following the discovery by MacKenzie and MacKenzie (1943) that the feeding of sulfaguanidine depressed the basal metabolic rate of rats, attempts were made to determine the effect of feeding closely related compounds to poultry and swine. Kempster and Turner (1945) conducted two trials with New Hampshire chicks in which one-half the birds were fed a ration containing 0.2 percent thiouracil. A 16-day feeding period neither altered the gain in weight nor improved the carcass grade. Feeding thiouracil for 36 days, however, reduced the rate of growth and increased the amount of feed required to produce a pound of gain but improved the carcass grade. Muhrer and Hogan (1945) pair-fed four groups of swine on rations identical except for the addition of 0.2 percent of thiouracil to the ration of the experimental animals. After 28 days, the experimental animals were shorter and fatter and had gained weight more rapidly and economically than had the controls.

The purpose of our investigation was to determine the optimum amount of thiouracil to include in the ration of swine and to ascertain whether this amount resulted in more economical gains.

[1] Journal Series Paper of the New Jersey Agricultural Experiment Station, Rutgers University, Departments of Animal and Dairy Husbandry, New Brunswick, N. J.

Materials and Methods

This work was carried out on one of the State Farms[2] and the ration fed, although not of high quality, was compounded on the basis of available ingredients. In the first trial, the basal ration consisted of: 800 lbs. ground corn; 800 lbs. ground barley; 50 lbs. soy bean meal; 50 lbs. alfalfa meal; 40 lbs. Maniodized Calcite; 160 lbs. 40% hog supplement; 50 lbs. fish meal; and 50 lbs. meat scrap or meat and bone meal. In the second trial, the basal ration consisted of: 1100 lbs. ground corn; 340 lbs, ground barley; 50 lbs. distillers solubles; 50 lbs. alfalfa meal; 40 lbs. Mico; 50 lbs. fish meal; 50 lbs. meat scrap; and 320 lbs. Provico Pig and Hog Mix (50% concentrates, 30% corn, 10% wheat, and 10% oats). Berkshire hogs were used throughout.

In the first trial, four groups, each comprising four hogs, were employed. These hogs had well-developed frames but they were rather thin. Group 1 received the basal ration only and served as a control group. The rations for groups 2, 3, and 4 contained 0.15, 0.20, and 0.25 percent of thiouracil[3] respectively. Each group was hand-fed twice daily all they would consume, for a 45-day period.

In the second trial, two groups, each consisting of five gilts and five barrows were used. The ration of the experimental group contained 0.25 percent thiouracil, since the first trial showed that, of the three levels of thiouracil fed, this was the optimum. The feeding trial extended over a 38-day period, and the hogs were self-fed.

The hogs were weighed by groups at the beginning and at the end of the experiment.

Results and Discussion

In the first trial, the control group gained a total of 200 pounds in weight in 45 days and consumed 820 pounds of feed for each 100 pounds of gain. The average daily gain was 1.11 pounds. Group 2 gained 220 pounds in weight and consumed 756 pounds of feed for each 100 pounds of gain. The average daily gain was 1.22 pounds. Group 3 made an average daily gain in weight of 1.25 pounds. The total gain in weight was 225 pounds, and the feed consumption was 724 pounds for each 100 pounds of gain. Group 4 gained a total of 250 pounds in weight or 1.39 pounds a day. This group consumed only 651 pounds of feed per 100 pounds gain in weight as contrasted with the 820 pounds consumed by the control group. These results are summarized in table 1.

[2] This investigation was carried on at the Bordentown State Prison Farm. Acknowledgment is made to William Houston and Richard Wills for their permission to carry on the experimental work and to Michael Lisehora, Swine Herdsman, for his assistance.

[3] The thiouracil (Deravet) was kindly furnished by the Lederele Laboratories, Pearl River, New York, through the courtesy of Dr. Mark Welsh.

In the second trial, group 6, which received the thiouracil, gained a total of 610 pounds in weight in 38 days as compared with 470 pounds gained by group 5, which served as a control. The average daily gain of group 6 was 1.60 pounds, while that of group 5 was 1.23 pounds. Group 6 consumed 524 pounds of feed for each 100 pounds of gain as compared with 723 pounds of feed consumed by group 5 for each 100 pounds of gain (table 2).

TABLE 1. INFLUENCE OF THIOURACIL ON WEIGHT GAINS AND FEED CONSUMPTION IN SWINE

Group No.	Thiouracil treatment*	No. of animals	Initial weight	Final weight	Gain in weight, 45 days	Total feed consumed	Feed consumed per 100 lbs. gain	Average daily gain
			lbs.	lb	lbs.	lbs.	lbs.	lbs.
1	Control	4	930	1130	200	1640	820	1.11
2	0.15	4	930	1150	220	1664	756	1.22
3	0.20	4	850	1075	225	1628	724	1.25
4	0.25	4	840	1090	250	1628	651	1.39

* Percentage of thiouracil in feed.

TABLE 2. INFLUENCE OF 0.25 PERCENT THIOURACIL ON WEIGHT GAINS AND FEED CONSUMPTION IN SWINE

Group No.	Thiouracil treatment*	No. of animals	Initial weight	Final weight	Gain in weight, 38 days	Total feed consumed	Feed consumed per 100 lbs. gain	Average daily gain
			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5	Control	10	2090	2560	470	3400	723	1.23
6	0.25	10	2200	2810	610	3100	524	1.60

* Percentage of thiouracil in feed

From the results of these two trials, it appears that the feeding of thiouracil to swine may result not only in more economical gains but also in more rapid gains. The feed consumed per 100 pounds of gain in weight is high in all of the groups. This can be attributed partly to the rather low quality of the ration fed. Nevertheless, in all cases the economy of gain is in favor of those groups fed thiouracil.

To produce an increase of 100 pounds in body weight, the hogs in group 6 required 27.5 percent less feed than did those in the control group 5. In addition, the rapidity of gain was greater in the experimental group. This

difference, however, is not so great as that reported by Muhrer and Hogan (1945). Undoubtedly, the differences in Muhrer and Hogan's work would not have been so great had the control animals been fed all they would consume instead of being held to the same feed intake as that of the experimental animals. In our work both the control and experimental groups were fed all they would consume. It appears to us that it is under these conditions that the feeding of thiouracil must prove to be advantageous if it is to have any practical application in swine husbandry.

Summary

Hogs fed a ration containing 0.25 percent thiouracil consumed 27.5 percent less feed per 100 pounds of gain in body weight than did hogs fed the same ration but containing no thiouracil. The thiouracil-fed hogs made an average daily gain of 1.60 pounds, whereas the control hogs gained 1.23 pounds per day.

The inclusion of 0.25 percent of thiouracil in the feed was more effective than either 0.15 or 0.20 percent.

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THE EFFECT OF THIOURACIL ON THE GROWTH AND FATTENING OF YEARLING STEERS[1]

W. M. Beeson, F. N. Andrews and P. T. Brown[2]
Purdue University Agricultural Experiment Station

IT HAS long been known that the thyroid gland is vitally concerned with general body metabolism, metamorphosis, growth and development. There is some evidence that fat metabolism and deposition may be influenced by thyroid activity; although obesity is frequently associated with hypothyroidism in the human this is not always the case and some hypothyroid humans exhibit subnormal fat deposition. However, the treatment of hyperthyroid humans by thyroidectomy and by the administration of thyroid depressing substances (Astwood, 1943, 1943a) is frequently followed by increased body weight.

Andrews and Bullard (1940), and Bullard and Andrews (1943) found that partial thyroidectomy of beef steers was followed by markedly increased rates of gain during the first six to eight postoperative weeks. Individual steers gained up to five pounds daily for two to six weeks but in all cases the rate of gain decreased and approached normal after six to eight weeks. This was attributed to hypertrophy and hyperplasia of the thyroid remnants and it was concluded that satisfactory hypothyroidism could not be produced by the surgical alteration of thyroid function.

The discovery that a large number of substances related to thiourea (and other goitrogens) inhibit thyroxine secretion, decrease basal metabolic rate, and produce thyroid hypertrophy and hyperplasia in the rat, opened a new approach to the study of hypothyroidism in farm animals (Richter and Clisby, 1942; Kennedy, 1942; Astwood and co-workers, 1943, 1943a, 1944, 1945; MacKenzie and MacKenzie, 1943; McGinty and Bywater, 1945).

Turner *et al.* (1944) reported that thiourea and thiouracil will completely stop thyroxine secretion in cattle, sheep and goats when administered in sufficient quantities. Kempster and Turner (1945) found that thiouracil improved the market quality of broilers. Andrews and Schnetzler (1946) reported that when thiouracil was fed at a level of 0.20 percent the market quality and fat deposition of broilers was significantly increased. Growth rate was somewhat reduced but the efficiency of feed utilization was increased. Muhrer and Hogan (1945) reported that the addition of thiouracil to the ration of fattening swine reduced feed intake but increased fat deposition and feed efficiency. Andrews *et al.* (1946) found that thiouracil intakes

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of 0.175 gm. to 0.544 gm. per lamb per day slightly reduced the rate of growth in all lots receiving thiouracil but these differences were not significant. Thiourea significantly reduced growth rate when fed at levels ranging from 0.048 to 0.071 gm. per lamb daily. Feed intake was somewhat reduced in all groups receiving thiouracil and thiourea and there was a tendency for gross feed efficiency to be reduced by these drugs. Carcass quality appeared to be superior to the controls in the lambs receiving 0.175 and 0.333 gm. of thiouracil daily.

Material and Methods

Yearling Hereford feeder steers, which had been previously wintered and pastured in Indiana, averaging approximately 790 pounds in weight were used in this experiment. Five lots of 10 steers each were grouped on the basis of body weight and general similarity in type and fed from November 28, 1945 to May 1, 1946, a period of 154 days.

All lots were full fed a daily basal ration of corn and cobmeal, 13.57 lb.; soybean oil meal, 2.23 lb.; corn silage, 12.93 lb.; mixed clover-timothy hay, 2.86 lb.; and free access to loose salt and steamed bonemeal.

After the steers had been on feed 56 days, thiouracil was incorporated in the soybean oil meal in quantities that would provide 2.0 gm., 4.0 gm. and 6.0 gm. of thiouracil per steer daily in lots II, III and IV, when the steers consumed 2.0 pounds of soybean oil meal. Additional amounts of soybean oilmeal were fed to each group without thiouracil. In order to assist in masking the bitter taste of thiouracil, 1.0 percent of salt was added to the soybean oil meal-thiouracil mixture. At the same time the steers in lot V were fed thiouracil in the salt at a rate of 1 to 10 parts by weight, for 28 days. If the steers had consumed salt at a normal intake of 0.05 pound daily this would have allowed an intake of approximately 2.0 grams of thiouracil daily per steer. However, the steers ate very little of the salt-thiouracil mixture and the method of feeding was changed by adding the thiouracil to the bonemeal in the same ratio and giving the steers free access to salt separately for the remainder of the feeding period. By this method of feeding it was not possible to maintain a very high level of thiouracil intake (only 0.11 gm. per steer daily).

The steers were weighed individually on three consecutive days at the beginning and close of the experiment, and at 28-day intervals during the trial. Group weights were taken every 14 days. The dressed weights were obtained at the time of slaughter, and the carcasses were officially graded according to Federal standards by a Federal grader.

The thyroid glands were removed from each steer at the time of slaughter, gross fresh weights were obtained and tissues were prepared for microscopic examination.

The data were treated statistically by the method of analysis of variance (Snedecor, 1946).

Results

Growth Rate

The data summarizing the effects of thiouracil on growth rate are presented in table 1. The addition of thiouracil to the ration at levels of 2.0 to 6.0 gm. per steer daily had no significant effect on the rate of growth as measured by total gain in weight. The gain ranged from 2.26 to 2.50 pounds per steer daily and was slightly increased in the lots which received 2.0 and 4.0 gm. of thiouracil per steer daily. Since all of the animals made excellent daily gains these data indicate that when thiouracil was fed at these levels rate of gain was not depressed.

Feed Consumption

The steers in each lot were full-fed throughout the experiment. It was not planned to limit the feed intake of any of the lots to that of the lowest lot, and this was not necessary since the consumptions of all groups were voluntarily maintained at almost identical levels. The steers in lot V were used for a study of the techniques of thiouracil administration. After the 56th day of the experiment the cattle in this lot were fed thiouracil in the salt at a ratio of 1 to 10 for 28 days. This mixture was so unpalatable that the steers limited their salt intake to an inadequately low level and thus practically no thiouracil was ingested. From 85th to 154th day the thiouracil was mixed with bonemeal in a ratio of 1 to 10 and was available to the steers at all times. This mixture was likewise unpalatable and the average thiouracil intake from the 57th to the 154th days was only 0.11 gm. per steer. Both of these methods were poor ways of administering thiouracil. Thiouracil was readily consumed when fed mixed with the basal ration in amounts up to 6.0 gm. per animal daily.

Efficiency of Feed Utilization

The data on efficiency of feed utilization were not adapted for statistical analysis and it is unlikely that the small differences are significant. However, it should be pointed out that the animals receiving 2.0 and 4.0 grams of thiouracil daily gained more rapidly and required slightly less feed per pound of gain than any of the other groups. These data are summarized in table 1.

Thyroid Changes

Data on the influence of thiouracil on thyroid weight are summarized in table 2. Thyroid weight was significantly increased by an intake of 4.0 grams

TABLE 1. EFFECT OF THIOURACIL ON THE GROWTH AND FATTENING OF YEARLING STEERS. THERE WERE TEN STEERS PER LOT, FED 154 DAYS

Item	Unit	Lot number and thiouracil fed daily per steer				
		I None	II 2.0 gm.	III 4.0 gm.	IV 6.0 gm.	V Free access in salt and bonemeal
Growth Rate						
Av. initial wt.	lb.	792	787	789	789	789
Av. final wt.	lb.	1159	1171	1171	1156	1137
Total gain per steer	lb.	367	384	377	367	348
Daily gain per steer	lb.	2.39	2.50	2.44	2.38	2.26
Daily Feed Consumption per Steer						
Corn and cobmeal	lb.	13.57	13.57	13.57	13.57	13.57
Soybean oilmeal	lb.	2.23	2.23	2.23	2.23	2.23
Corn silage*	lb.	12.93	12.93	12.93	12.93	12.93
Clover-timothy hay	lb.	2.83	2.84	2.81	2.89	2.81
Bonemeal	lb.	.030	.027	.026	.023	.002
Salt	lb.	.051	.075	.053	.039	.026
Thiouracil	gm.		2.00	4.00	6.00	.11
Total (Air dry basis*)		22.621	22.622	22.569	22.632	22.518
Feed Required per Pound of Gain						
Corn and cobmeal	lb.	5.68	5.44	5.55	5.70	6.00
Soybean oilmeal	lb.	.93	.89	.91	.93	.99
Corn silage*	lb.	5.42	5.18	5.29	5.43	5.73
Clover-timothy hay	lb.	1.20	1.14	1.15	1.21	1.24
Bonemeal	lb.	.01	.01	.01	.006	.001
Salt	lb.	.02	.03	.02	.02	.01
Thiouracil	gm.		.75	1.49	2.45	.05
Total (Air dry basis*)		9.47	9.06	9.23	9.476	9.961

* Corn silage was converted to 90% dry matter basis.

of thiouracil per steer daily. When the level was 2.0 grams or less per steer per day thyroid weight was not affected. The reduction in size between the thyroids of the steers in lots III (104.9 gm.) and IV (87.8 gm.) would appear to need explanation. It is possible that long continued ingestion of thiouracil at high levels may eventually result in decreased thyroid size. This same phenomenon has been observed by the authors in sheep.

Carcass Studies

Although the lot differences in dressing percentage were not statistically

significant, it is interesting to observe that all of the lots receiving thiouracil had somewhat higher yields than the controls. These differences approach significance in lots II, III and V (table 2).

The distribution of official federal carcass grades of the lots is summarized in table 2. The grades were assigned the following numerical values and an analysis of variance was performed: AA = 1; and A = 2. Assigning arbitrary numerical values for the official grades is subject to some criticism, but has the advantage of making the data suitable for limited statistical treatment. There was an indication that the carcasses in lots III and IV tended to be

TABLE 2. EFFECT OF THIOURACIL ON THYROID WEIGHT, CARCASS YIELD AND CARCASS GRADE OF STEERS

Item	Unit	Lot number and thiouracil fed daily per steer					Least significant difference at 5% level
		I None	II 2.0 gm.	III 4.0 gm.	IV 6.0 gm.	V Free access in salt and bone-meal	
Average thyroid wt.	gm.	69.7	61.3	104.9	87.8	63.8	32.0
Average dressing percentage	%	59.17	60.47	60.36	59.53	60.83	1.85
Carcass grades							
AA	%	60	50	70	70	40	
A	%	40	50	30	30	60	
Numerical index value[1]	Index	1.4	1.5	1.3	1.3	1.6	0.46

[1] Obtained by assigning a value of 1 for = grade AA and 2 for A.

fatter than the control group. However, the data show that there was no significant improvement in carcass quality in the groups receiving thiouracil.

Discussion and Application of Results

Since thyroid secretion is necessary for normal growth and development it would be expected that sufficient inhibition of thyroid function by goitrogenic agents would depress growth. In most species thus far studied the growth of immature animals has been depressed by thiouracil and thiourea.

Astwood *et al.* (1944) showed that when thiouracil was added to the feed of newly hatched chicks at a level of 0.5 percent, growth was markedly retarded. When thiouracil was fed to pregnant or suckling rats and/or their young, growth was retarded and changes similar to those seen in cretinism

were produced (Astwood, 1943; Hughes, 1944; Goldsmith *et al.*, 1945). Andrews and Schnetzler (1946) reported that the addition of thiouracil to the rations of growing chickens at levels varying from 0.025 to 0.20 percent tended to reduce growth. Analysis of the data showed that the depression in rate of gain was highly significant in males receiving 0.20 per cent thiouracil and exposed to 1½ hours of artificial light during the night. The rate of growth of similarly treated females was reduced, although not significantly. According to Andrews *et al.* (1946) thiouracil intakes of 0.175 gm. to 0.544 gm. per lamb per day had no significant effect on rate of growth as measured by total gain in weight, although the growth rate was slightly reduced in all lots receiving thiouracil. Calculated on a percentage basis, the lambs received levels of thiouracil ranging from 0.01 to 0.08 percent of the total ration. In yearling steers the rate of gain appears to have been increased in the steers which received 2.0 and 4.0 grams of thiouracil daily and was equal to the control lot in the animals which were fed 6.0 gm. thiouracil daily. The differences were not significant, but this was the authors' first experience in which rate of gain appeared to be increased instead of depressed. Thiouracil intake calculated on the basis of percentage of the total air dry ration ranged from 0.02 to 0.06 percent. This is much less than the amounts which have been fed to chickens, rats, and hogs. Muhrer and Hogan (1945) reported that when thiouracil was fed to swine at a level of 0.20 percent of the diet and the feed intake of the controls limited to that of thiouracil group, the rate of gain of the thiouracil hogs was highly significantly increased. However, the authors point out that the growth of the controls was inhibited by restricted feeding.

It has been observed by the authors that swine and sheep object to the bitter taste of thiouracil as evidenced by reduced feed intake of rations containing this drug. There was no evidence of reduced feed intake when thiouracil was incorporated in the steer rations at levels of 2.0, 4.0 and 6.0 gm. daily. Data on Muhrer and Hogan (1945) indicated that when 0.20 percent thiouracil was added to a swine ration the feed intake was markedly reduced and the controls would have consumed more food by ad libitum feeding.

Although the data on the efficiency of feed utilization do not lend themselves to statistical treatment, it should be pointed out that the steers which received 2.0 and 4.0 gm. thiouracil daily required slightly less feed per pound of gain than the control. Part of this increased efficiency may be attributed to the increased rate of gain in lots II and III. This is similar to the findings of Andrews and Schnetzler (1946) that in both male and female chickens fed 0.20 percent thiouracil the efficiency of feed utilization was greater when adjusted for gain by the analysis of covariance. Andrews *et al.* (1946) reported that there were no differences detected

in feed efficiency in lambs receiving up to 0.333 gm. of thiouracil per day, and a distinct tendency for increased feed requirement per pound of gain in the lots receiving thiourea and the higher levels of thiouracil. Muhrer and Hogan (1945) reported highly significant increases in feed efficiency for thiouracil fed swine when feed intake of the controls was limited. This has not been observed in swine fed ad libitum at this station.

Thyroid weight was increased 50 percent in steers receiving 4.0 gm. of thiouracil daily and final thyroid size was not affected by the consumption of 2.0 gm. thiouracil daily for 98 days. Steers which received 6.0 gm. thiouracil showed less thyroid tissue based on final gland weight than animals receiving 4.0 gm. thiouracil. These and unpublished data suggest that on higher thiouracil intakes thyroid hypertrophy and hyperplasia may be followed eventually by glandular atrophy. Further studies on this problem are underway.

When thiouracil was fed to lambs at the level of 0.175 and 0.333 gm. daily, carcass quality was considerably improved (Andrews *et al.*, 1946), and it appeared that both cod and internal fat deposition were increased. Similar improvement in carcass quality has been reported in chickens by Andrews and Schnetzler (1946). Although the differences in carcass quality of the steers were small, there was a distinct tendency for the groups receiving the 4.0 and 6.0 gm. levels of thiouracil to be fatter.

It was observed by us and others that the thiouracil fed cattle were more docile, less active and less subject to excitement.

Summary

Thiouracil intakes of 2.0 to 6.0 gm. per steer per day did not depress the rate of growth of yearling steers, and the rate of gain appeared to be slightly increased in the groups receiving 2.0 and 4.0 gm. thiouracil daily.

Feed consumption was not influenced by the addition of 2.0 and 6.0 gm. of thiouracil to the daily ration of the steers. Efficiency of feed utilization was not significantly affected by thiouracil but there was a tendency for the steers receiving 2.0 to 4.0 gm. thiouracil to require less feed per pound of gain.

Thyroid weight was significantly increased by the ingestion of 4.0 gm. thiouracil daily.

Dressing percentage and degree of finish were not significantly effected by thiouracil but there was a tendency for improvement of both of these characteristics by the drug.

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HEAT TOLERANCE COMPARISONS BETWEEN JERSEY AND HOLSTEIN COWS

D. M. Seath and G. D. Miller
Louisiana Agricultural Experiment Station

AMPLE evidence has been published showing that *Bos indicus* cattle are more tolerant to high atmospheric temperatures than are *Bos taurus* cattle. As pointed out by Rhoad (1938, 1941) *Bos indicus*, or zebu, as represented by the Brahman (guzerat) animals had much more heat tolerance than did Angus cattle. Crossbreds were intermediate between the two types. Jerseys were found to be somewhat superior to one-fourth zebu and three-fourths Angus crossbreds. Rhoad reports that dairy strains of zebu cattle are being bred in India and that crossbreds carrying some zebu blood are to be found in Brazil, Jamaica, and the Philippine Islands, and the various Indian breeds are described by Phillips (1944), together with information on their milk-producing capacities.

Comparative tests made by Freeborn *et al.* (1934) showed that Holsteins were higher in body temperature than were Jerseys at air temperatures of 75°, 80°, and 85° F. The body temperatures they reported for Jerseys are similar to those found by Gaalaas (1945) in Louisiana for the same atmospheric temperatures.

Riemerschmid and Elder (1945) reported wide variations between breeds of cattle in the amounts of solar radiation absorbed by the skin. They found that absorption was markedly dependent upon color, with white Zulu coat absorbing only 49 percent of the rays and the black Angus coat 89 percent. A comparison of different shades of red showed percentages of absorption varying from 78 to 83 percent. Clipping the curly Sussex winter hair coat produced a 2 percent reduction in absorption.

Studies in Louisiana (Seath and Miller 1946a, 1946b) have shown that high air temperatures markedly affected body temperatures and respiration rates of milking Jersey and Holstein cows with only a slight effect on their pulse rates. Changes in air temperature also greatly influenced daytime grazing time. In the same studies it was found that high humidity had only a slight effect on body temperature, respiration rate and pulse rate of the cows.

Procedures

Data used in the present study were secured from milking cows of the Louisiana State University dairy herd. The cows were handled in two separate dairy units and each unit included both Jersey and Holstein cows. In 1944 there were 36 Holsteins and 16 Jerseys, while the 1945 observations

were made on 41 Holsteins and 27 Jerseys. Only 13 Holsteins and 8 Jerseys were the same cows for the two years.

Respiration rates were secured from counts made of flank movements and body temperatures from readings made with veterinary thermometers inserted approximately three inches into the rectum. Pulse rates were secured by placing tips of fingers next to coccygeal arteries on under side of tail. In most cases respiration and pulse rates were checked by two people and when there was a lack of agreement a third count was made. These records were secured from 10 to 30 minutes after the cows entered the milking barn (at approximately 3:00 P.M.) and before they were fed grain.

During 1944 records were secured on consecutive days twice weekly, starting on August 28 and ending on October 14. In 1945 each herd was observed on 15 different days, with these days falling between July 16 and August 3 for one herd and between August 6 and August 24 for the other.

A sling psychrometer was used to secure wet- and dry-bulb temperature records at the time of each observation. Appropriate standard weather bureau tables were used to determine relative humidity from the readings secured.

Results

Atmospheric Conditions Prevailing

Variations in air temperature and humidity were sufficiently large for each of the two years (table 1) to permit a good comparison of Jersey and Holstein cows under varying summer climatic conditions. For example, air

TABLE 1. AIR TEMPERATURE AND RELATIVE HUMIDITY FOR PERIODS COVERED IN THE EXPERIMENT

Items compared	1944 (26 observation periods)			1945 (15 observation periods)		
	Range	Mean	Standard deviation	Range	Mean	Standard deviation
Air temperature (°F.)	65–93	85.1	6.17	75–91	85.6	4.75
Relative humidity (%)	27–91	56.8	14.06	51–91	73.5	10.00

temperatures during the periods of test varied in 1944 from 65 to 93° F. and averaged 85.1° F., and in 1945 ranged from 75 to 91° F. with an average of 85.6° F. Discontinuing observations in 1945 before fall weather arrived contributed toward the lower standard deviations than were found the previous year for both air temperature and percent humidity. The range in relative humidity was from 27 to 91 with an average of 56.8 percent in

1944, while in 1945 the range was from 51 to 91 with an average of 73.5 percent.

General Observations

Jersey and Holstein cows, when handled side by side in the University herds, have shown similar variations in production due to changes in feed and weather. (An accurate check on this point is to be made later.) On hot days members of each breed seek shelter of shade at about the same time

TABLE 2. BREED AVERAGES FOR BODY TEMPERATURE, RESPIRATION RATE AND PULSE RATE DURING PERIODS COVERED IN EXPERIMENT

Breed	1944 (26 observation periods)			1945 (15 observation periods)		
	Range	Mean	Standard deviation*	Range	Mean	Standard deviation*
			Rectal temperature (°F.)			
Holsteins	100.2–106.5	103.3	1.33	100.0–106.0	103.5	1.11
Jerseys	100.3–105.6	102.6	0.94	99.0–105.9	102.7	1.12
			Respirations per minute			
Holsteins	21–129	67.4	23.0	28–129	80.4	18.24
Jerseys	22–128	69.9	25.4	23–143	75.9	21.55
			Pulse rate per minute			
Holsteins	40–91	67.7	6.07	32–94	70.6	6.94
Jerseys	50–99	65.9	6.12	53–99	70.0	7.13

* Standard deviations were calculated on an intra-herd basis.

following a morning's grazing period of about two hours (Seath and Miller, 1946a). As contrasted to this, a great difference was noted between the two breeds in the condition of the cows when they entered the milking barn in the evening. The Holsteins were usually covered with mud and dirt on hot days as a result of lying in mud and water located in shady spots. while Jerseys were seldom in this condition. Jerseys evidently had less need of the cooling effect of mud and water. Those that desired this cooling treatment may have been prevented from securing it by Holsteins, which have the advantage of size.

Breed Averages for Body Temperature, Respiration and Pulse

The most pronounced difference found between the Jerseys and Holsteins when all data were summarized on a yearly basis (table 2) was for

body temperature. In 1944 the Holsteins with a body temperature average of 103.3° F. exceeded Jerseys in that respect by 0.7° F. The range and the intra-herd standard deviation were also higher for Holsteins than for Jerseys. This took place when air temperatures averaged 85.1° F.

In 1945 the air temperature average of 85.6° F. was practically the same as in 1944. Body temperatures of Holsteins in 1945 averaged 103.5° F., or 0.8° higher than that of Jerseys; but in this case little difference was found between the breeds in either range or standard deviation.

On the basis of respiration and pulse rates (table 2) there appears to be little consistency in the rating of the two breeds. In 1944, for example, Jerseys ranked highest in respiration rate with 69.9 times per minute with Holsteins 2.5 times per minute less, while in 1945 Holsteins were highest with 80.4 and the Jerseys averaged 75.9. Holsteins were highest in pulse rate in 1944 (67.7 times per minute as compared to 65.9), but in 1945 the two breeds each averaged approximately 70 times per minute. Of doubtful significance is the fact that the intra-herd standard deviation was highest for Jerseys during each of the two years for both respiration and pulse rates.

Reactions to Changes in Air Temperature and Relative Humidity

An examination of figures 1 and 2 reveals, in general, how closely changes in air temperature and percent relative humidity were accompanied by changes in body temperature, respiration rate, and pulse rate of the groups of Jersey and Holstein cows. For each of the two years the average reactions are shown separately for the two breeds. The trends shown make it readily apparent that air temperature changes are in most cases accompanied by similar changes in body temperature and respiration rate. During a majority of the test periods body temperatures of Holsteins averaged higher than did those for Jerseys.

Pulse rate changes indicate only a small relationship to air temperature changes and those shown vary much between years and between barns. The influences of increases or decreases in percent relative humdity on body temperature, respiration rate, and pulse rate are not readily apparent from a study of figures 1 and 2.

Correlations on an intra-herd basis (table 3) were computed in an effort to determine if the two breeds reacted differently to changes in air tempera ture and humidity. When air temperature was thus studied partial correla-tion was used to hold humidity constant. In reverse order, air temperature was held constant when the influence of humidity was studied.

On the basis described the body temperature and air temperature correlation was highest for Holsteins in 1944 ($r = 0.751$) with Jerseys ranking first in 1945 (0.530). Respiration and air temperature were most highly correlated

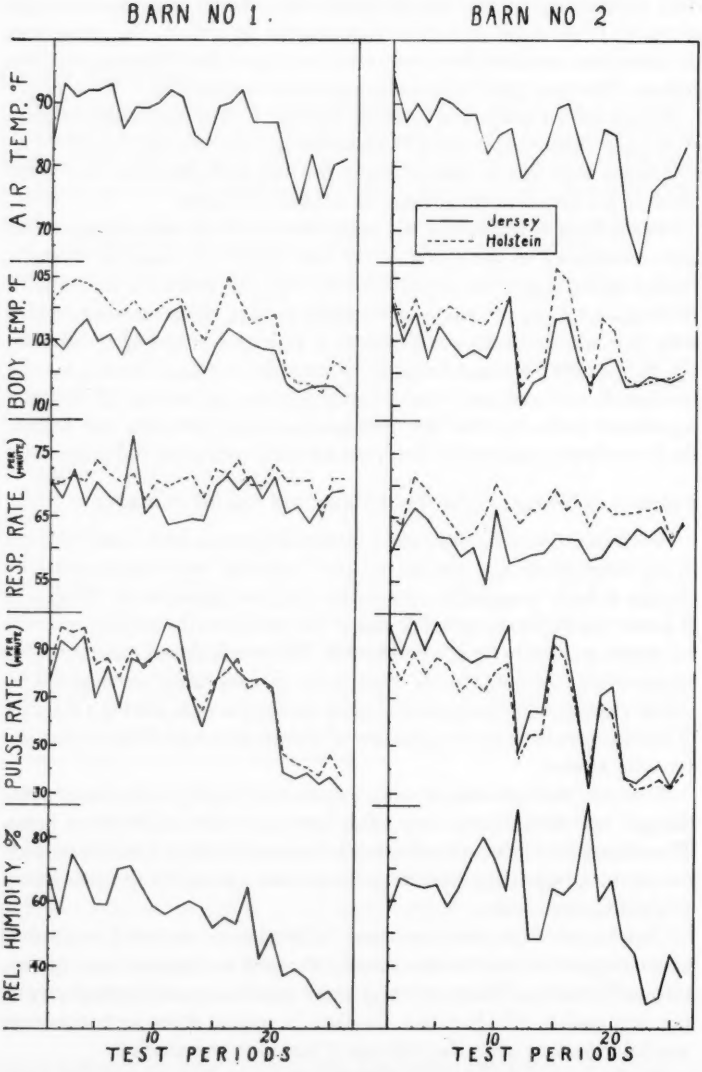

Figure 1. Air temperature, body temperature, respiration rate, pulse rate, and relative humidity for 26 observation periods by barn for 1944. Jersey data are shown by solid line and Holstein data by broken line.

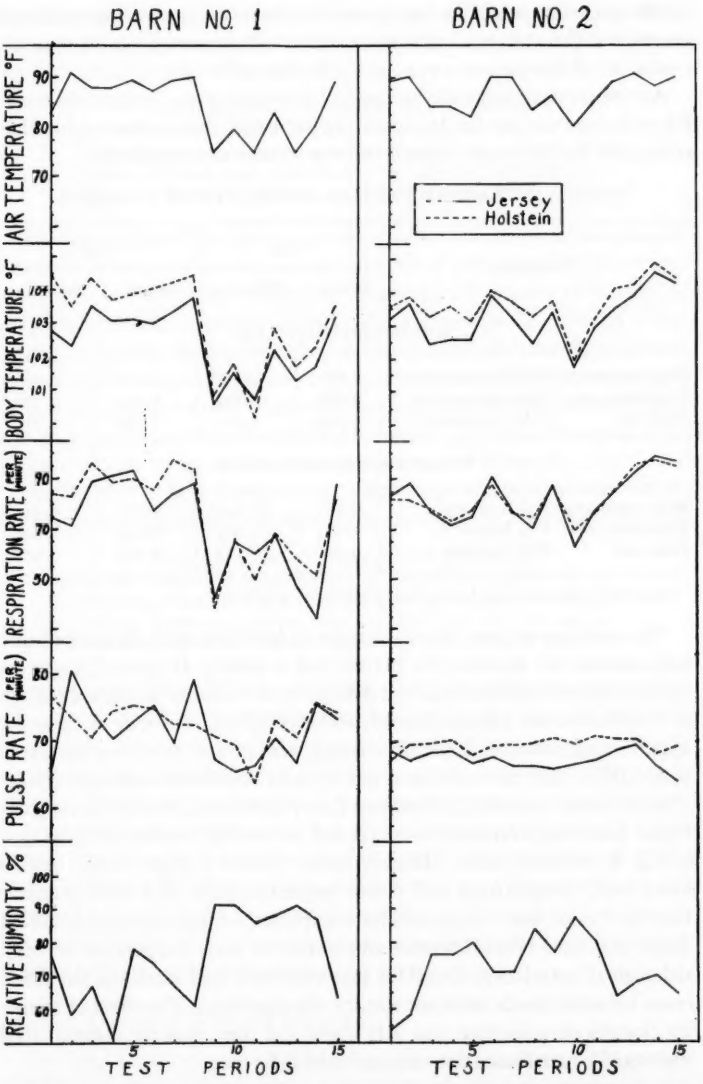

Figure 2. Air temperature, body temperature, respiration rate, pulse rate, and relative humidity for 15 observation periods by barn for 1945. Jersey data are shown by solid line and Holstein data by broken line.

for Holsteins for each of the two years, but the partial correlation coefficient was only slightly larger in 1945, i.e., 0.370 as compared to 0.334. In 1944 the r value for Holsteins was 0.774 and for Jerseys 0.685.

Air temperature and pulse rate partial correlations are all relatively small. For each year the one for Jerseys is slightly larger than is the one for Holsteins, but the difference is small and not statistically significant.

TABLE 3. INTRA-HERD PARTIAL CORRELATIONS BY BREEDS

Variables	1944		1945	
	Jerseys	Holsteins	Jerseys	Holsteins
With humidity held constant				
Body temperature × Air temperature	0.607	0.751*	0.530	0.499
Respiration rate × Air temperature	0.685	0.774*	0.334	0.370
Pulse rate × Air temperature	0.119	0.102	0.186	0.125
With air temperature held constant				
Body temperature × % humidity	0.135	−0.341*	0.052	−0.025
Respiration rate × % humidity	0.254	−0.294*	−0.037	−0.029
Pulse rate × % humidity	0.016	−0.024	0.043	0.071

* Significantly different from that for other breed at 5% level of probability.

The reactions of cows due to changes in humidity with air temperature held constant are shown in the bottom half of table 3. In general, it appears that Jerseys and Holsteins reacted differently to humidity changes, although all correlations are relatively small, and especially is this true of those for 1945. In 1944, however, humidity changes were greater than was the case in 1945 (table 1) and the reactions as indicated by correlation coefficients (table 3) indicate that as humidity increased Jersey cows on an average had slightly higher body temperatures ($r = 0.135$) and accelerated respiration rates ($r = 0.254$). In reverse order, Holstein cows showed a slight trend toward lower body temperatures and slower respiration rates. For body temperature the r value was -0.341 and for respiration -0.294. To a much smaller degree this same breed difference was shown for body temperature in 1945, although all correlations found for that year were very small and the differences between breeds were not statistically significant. The effect of humidity changes on pulse rate was only slight and there was no uniform trend that could be attributed to a definite breed difference.

Rate of Change in Body Temperature and Respiration

Multiple regression equations when computed on the basis of securing

the influence of changes in both air temperature and humidity on the body temperature of Jersey and Holstein cows resulted as follows (T = air temperature and H = relative humidity):

(Body temperature × Air temperature × % humidity)

1944—Jerseys, Estimated body temperature = 0.1007 T + 0.00758 H + 93.65
Holsteins, Estimated body temperature = 0.1919 T − 0.0321 H + 88.85
1945—Jerseys, Estimated body temperature = 0.1768 T + 0.00636 H + 87.17
Holsteins, Estimated body temperature = 0.1721 T − 0.00303 H + 88.91

An examination of the above regression coefficients shows an independent measure of changes in air temperature (T) and of humidity (H). For 1944 a one degree (F.) air temperature increase caused an increase of 0.1007° in body temperature of Jerseys and 0.1919° for Holsteins. In contrast, a one percent increase in relative humidity increased body temperature of Jerseys only 0.00758° and tended to lower body temperature of Holsteins 0.0321°. Only small differences were shown in size of regression coefficients for 1945, but again increases in humidity tended to cause a very small increase in body temperature of Jerseys, and a very small decrease in Holsteins.

On the basis of how changes in air temperature and relative humidity affected respiration rates, the multiple regressions reveal the answer as follows:

(Respiration rate × Air temperature × % humidity)

1944—Jerseys, Estimated respiration rate = 2.7724 T + 0.3447 H − 186.92
Holsteins, Estimated respiration rate = 3.3871 T − 0.4454 H − 194.68
1945—Jerseys, Estimated respiration rate = 2.3087 T − 0.1617 H − 108.93
Holsteins, Estimated respiration rate = 2.2307 T − 0.1204 H − 102.18

In but one case (Jerseys for 1944) did the regression coefficient for humidity (H) indicate an increase in respiration rate caused by an increase in humidity. In all other cases a small decline in respiration rate was shown to accompany an increase in relative humidity. There appeared to be a breed difference in effect of air temperature changes (T) on respiration rate. In 1944 Holsteins showed an increase in respiration of 3.3871 times per minute for each degree increase in air temperature as compared to a corresponding increase of 2.7724 times per minute for Jerseys. Thus, the Holstein rate of increase was 22 percent faster than that for Jerseys. No significant difference was shown between the breeds on this basis for 1945, when the influence of humidity changes appeared to be erratic and minor in importance.

Effect of Amount of White on Holsteins

For each of the two years all Holstein cows were classified on the amount of white spotting on their bodies. Two men made estimates on the percentage of total body surface that was white and the percentage of area above belly that was white. Averages of these estimates were used to group the

cows in an effort to determine relationship, if any, with body temperature, respiration rate or pulse rate of cows. Results of the study indicated no consistent tendency in this direction. If percentage of white did have an effect it was so small that it was overshadowed by other more important factors.

Discussion

The present investigation appears to confirm results of a previous study (Freeborn *et al.*, 1934) and the prevailing opinion among stockmen that Jerseys are more tolerant to high atmospheric temperatures than are Holsteins. Just how important this difference is from an economic viewpoint remains to be shown. One obstacle to obtaining an accurate answer to this problem is the inherited milk and butterfat production differences between the two breeds. Regardless of differences noted, the two breeds are both being used successfully on dairy farms in Southern states, although Jerseys far outnumber Holsteins.

If comfort of cows has any relationship to production, and there is good logic indicating that it should have, then the higher average body temperature of Holsteins of from 0.7 to 0.8° F. above that for Jerseys would be evidenced that as a breed they are less adapted to hot weather than are Jerseys. The fact that the Holstein cows repeatedly wallowed or lay in mud and water during the heat of the day, while Jerseys did little of this was evidence that those of the larger breed were more in need of some method to cool their bodies than were those of the smaller breed.

The finding that the rate of increase in body temperature in step with increases in air temperature (regression coefficient) was greater for Holsteins than for Jerseys was to be expected after observing that maximum readings, as well as mean values, were highest for Holsteins. Minimum body temperature readings, which in most cases are considered approximately normal under cool climatic conditions, were about the same for the two breeds.

As contrasted to a previous study (Seath and Miller, 1946b), the present data when analyzed separately by breeds indicate that changes in humidity had significant but opposite effects on body temperature and respiration rates of Jerseys and Holsteins. This was true for 1944 only. The differences between the reactions for the two years can possibly be explained by the greater number of test periods in 1944 and a wider variation in relative humidity, i.e., 27 to 91 percent in 1944 as compared to 51 to 91 percent in 1945. Multiple regression coefficients for 1944 indicate that a one percent increase in humidity tended to increase body temperature of Jerseys by 0.00758° F. but lowered it for Holsteins by 0.0321° F. Likewise, the effect on respiration rate was an increase of 0.00636 times per minute for Jerseys and a decrease by 0.00303 times per minute for Holsteins. These coefficients

are relatively small and vary from 1/6 to 1/57 the size of those which measure the independent effect of air temperature. Even so, should they represent the true influence of changes in humidity on these two breeds, an explanation would be in order, One could postulate that Holsteins derive some benefit from a high humidity because it tended to lower both body temperature and respiration rate. On the other hand a slowing-up in their respiration rate due to high humidity could help explain why their body temperatures average higher than those of Jerseys, for a decrease in respiration rate would lower the rate of heat elimination via the lungs.

Summary

Producing cows used in this study were handled as two separate dairy units at Louisiana State University. Each unit consisted of two dairy breeds and totaled in 1944 36 Holsteins and 16 Jerseys, and in 1945, 41 Holsteins and 27 Jerseys. Only 13 Holsteins and 8 Jerseys were the same cows for the two years. Observations made totaled 26 and covered a period of 13 weeks in 1944, while in 1945 only 15 observation days were used covering a much shorter period of time. Air temperature during days of observation varied in 1944 from 65 to 93° F. with an average of 85.1° F. In 1945 the range was from 75–91° F. with an average of 85.6° F.

Jersey and Holstein comparisons follow:

1. During 1944 the Holstein's body temperatures averaged 103.3° F. as compared to 102.6° F. for Jerseys. In 1945 the average for Holsteins 104.5 or 0.8° higher than for Jerseys.
2. Differences between breeds on the basis of respiration and pulse rates were small and not consistent as between years.
3. Minimum, or normal temperatures were about the same for the two breeds, with higher maximum temperatures registered by Holsteins.
4. Rate of increase of body temperature as the result of air temperature increase was greater for Holsteins than for Jerseys.
5. Data for 1944 only indicate that an increase in humidity tends to slightly increase body temperature and respiration rate of Jerseys with the opposite effect on Holsteins. In all cases changes in air temperature had a much greater influence than did changes in humidity.
6. Holstein cows on hot days frequented wet spots in the shade and would lie in mud and water. As a result they came into the milking barn in the evening covered with dirt and mud. Jerseys showed little tendency along this line.
7. The grouping of Holstein cows on the basis of percentage white on total body surface and percentage of body surface above belly that was white failed to reveal any relationship between amount of white

and heat tolerance. A tendency in this direction was probably overshadowed by other more important factors.

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EFFECTS OF ARTIFICIAL SHOWERS, NATURAL RAIN AND WALLOWING ON THE BODY TEMPERATURES OF ANIMALS

F. C. MINETT[1]

Imperial Veterinary Research Institute[2]

THE wetting of body surfaces increases heat loss as a result of evaporation, but little experimental work has been carried out to determine the extent to which this factor may affect body temperatures. This matter is of considerable importance in all countries, since many animals are not sheltered during storms and the exposure may affect their well-being and perhaps contribute to the incidence of disease. For example, certain diseases are more prevalent in India at the time of the monsoon, and this may possibly be associated with the chilling resulting from rainfall.

The results reported in this paper were obtained in a series of experiments designed to secure exact information on the effects of evaporation and wallowing on body temperatures under various conditions.

Material and Methods

Water buffaloes, zebu cattle, small hill cattle and sheep were used. In preliminary experiments, artificial showers of differing intensities and duration were used, followed by natural drying. This procedure was also modified, in some cases by roughly drying the animals immediately after the shower, and in other cases by giving the animals slight exercise before or during the shower (when there was necessarily some drying), or by giving slight exercise during the drying period at the end of the shower. Observations were also made on animals exposed to natural rain, and on water buffaloes that indulged in wallowing, a common practice in this species. Details of procedures are given in connection with the reports on the several experiments. Rectal temperatures were obtained to measure the effects of treatments.

Results and Discussion

Experiments with Artificial Showers

Twelve water buffaloes and six zebu (Hariana) cows were used. The work was done at Izatnagar during the winter, and during the hot-dry and monsoon seasons. Showers were usually given, beginning at 3:00 to 4:00 P.M., but in some cases they began about 7:00 A.M. Heavy artificial rain was

[1] The author is indebted to Col. C. E. MacGuckin, director of Military Dairy Farms for information kindly supplied, to M. S. Menon and K. C. Sinha for assistance in making observations, and to Suprakas Sen for statistical calculations.

[2] Mukteswar and Izatnagar, United Provinces, India.

usually applied for 2 to 4 hours, but for only 5 minutes in some cases. Light rain was applied for 3 to 6 hours. Water temperature was generally adjusted to about 55 to 60° F. Each experiment lasted 4 days. Only 2 animals could be accommodated in the experimental shed, and since it was desirable to obtain temperatures of the same animals on "wet" and "dry" days, the usual procedure was to select a period when air temperatures seemed to be fairly steady, then make body-temperature observations without showers on the first and third days and with showers on the second and fourth days.

Animals were tied in a closed shed, which had a concrete floor from which water drained readily. Heavy rain was obtained at first with 9 small nozzles,

TABLE 1. SUMMARY OF OBSERVATIONS ON FALL OF BODY TEMPERATURES IN WATER BUFFALOES AND ZEBU CATTLE AS A RESULT OF ARTIFICIAL SHOWERS

Experimental animals	Number of		Duration, type and time of artificial showers	Average temperature before showers	Average maximum fall in temperature
	Animals	Observations			
				degrees F.	*degrees F.*
Buffaloes	6	12	2 hrs., heavy, A.M.	100.23	2.81*
Buffaloes	4	35	2–4 hrs., heavy, P.M.	101.28	1.63*
Buffaloes	4	4	5 mins., heavy, A.M.	100.05	1.60
Buffaloes	2	4	5 mins., heavy, P.M.	101.22	0.60
Buffaloes	6	14	3–6 hr., drizzle, A.M. and P.M.	100.35	2.18
Hariana cows	4	21	2–4 hrs., heavy P.M.	101.80	0.49*

* The differences between 2.81 and 1.63 and between 1.63 and 0.49 are highly significant by the 't' test. However, it must be observed that the figure, 1.63, was obtained with castrated males and 0.49 with females.

fixed 10 feet from the floor and arranged so that the animals' backs were wetted uniformly. Later, a single nozzle was used. By both methods, a rainfall of 8 to 10 or more inches per hour could be readily produced. Light rain was obtained with a lawn-water sprinkler which gave 0.5 to 0.6 inches of rain per hour.

Rectal temperatures were taken every 30 minutes during the shower and for long as necessary (usually 2–4 hours) during the drying period. While drying the animals remained in the shed. In most experiments a draught of air was blown on the animals' backs from above and in front, two table fans (1,000 revs. per min. at full speed) being fixed at 6 feet from the floor and 5 feet from the middle of the back. At this distance and running at top speed each fan gave a breeze of 4 miles per hour velocity. Usually the fans were at full-speed during the shower and half-speed during drying. Air temperatures were recorded in the shed during the drying period. Full de-

tails of body and air temperatures are kept as Institute records; general results are given in this paper. Observations on the effects of showers on body temperature are summarized in table 1. These results, and the examples of reactions of individual animals illustrated in figures 1 and 2, show that the effect on body temperature of cattle is much less than on that of water buffaloes. In cows, the temperature may even rise slightly during the shower.

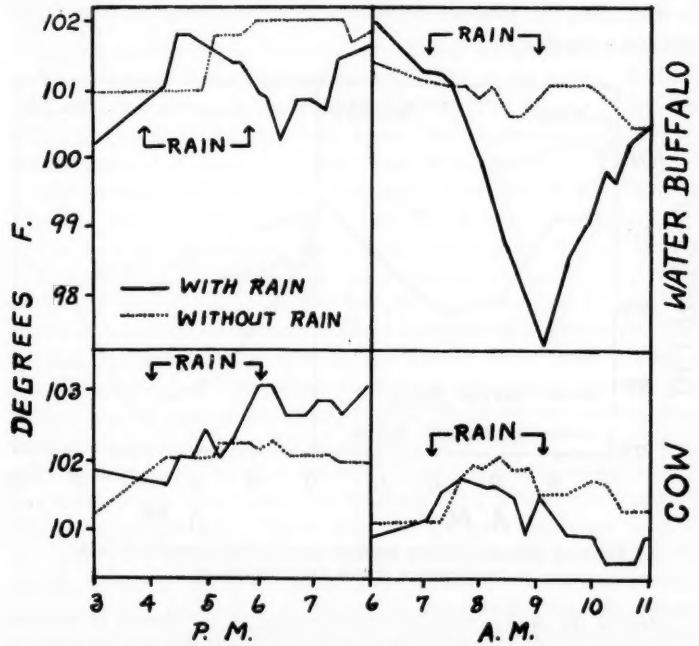

Figure 1. Effects of artificial showers on body temperatures of water buffalo cow No. 124 and zebu cow No. 174. Water temperature was 50–55° F. in all the tests. The afternoon observations were made on Jan. 4 (with rain) and Jan. 5 (without rain), and the morning observations on Jan. 10 (with rain) and Jan. 11 (without rain).

The different habits of the two species are indicated by the fact that the water buffalo appears to enjoy the shower, while cattle are resentful, especially at the first experience, and often shiver and adopt a crouching position.

The effects of a shower are greater in the morning than in the afternoon. This may be illustrated with data from ten adult water buffaloes that were arranged in two groups so that average weight, heart girth, height and hemoglobin values were about equal. The animals were given a heavy shower

of 1.55 to 1.90 inches in 5 minutes, group 1 at 8:00 A.M. and group 2 at 5:00 P.M. on the same day. Two days later the treatments were repeated with the groups reversed. The drops in body temperature were:

A.M.	P.M.
Group 1—1.62°	Group 2—0.0°
Group 2—1.42°	Group 1—0.76°

In both cases, the difference between A.M. and P.M. drops in temperature was highly significant.

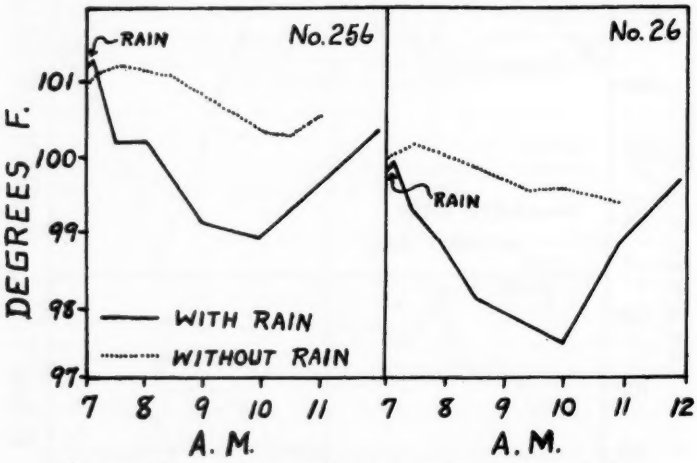

Figure 2. Effects of heavy artificial rain for five minutes on body temperature of two water buffaloes.

Most of the drop in temperature occurs during the shower in buffaloes and during the drying-off period in cows (see curves for A.M. in figure 1). Ratios between temperature drops during the shower and the drying period are about 1.0°:0.61° in the buffalo and 1.0°:2.9° in cattle. The drying of the wet coat in cows entails much loss of body heat, while buffaloes have little effect from drying of the coat. After a 2-hour drying period, the water buffalo's skin is practically dry, while that of cattle is still damp and even wet over the abdominal region.

The graphs in figure 2 show how a heavy morning shower of only five minutes can severely depress the water buffalo's temperature. Similarly, light rain from a sprinkler for three hours, beginning at 7:00 A.M., will lower the temperatures of young buffaloes. Such a shower does not always alter the temperature of older buffaloes, but if more prolonged will do so.

The effect of a current of air over the wet body was studied in three experiments, each with a pair of water buffaloes. During drying, one of each pair was standing in still air, while a fan, running at half speed, was directed on the other. In two of the experiments, the observations were repeated on another day with the animals reversed. In one of these two experiments the fanned buffalo had the lower temperature in both tests, and in the other on one day only. In the third experiment fanning made no appreciable difference.

The effect of drying the body after the shower was studied in two tests, each with a pair of water buffaloes. Immediately after the shower, the body of one member of the pair was roughly dried for three minutes, in one case with a cloth and in the other with straw. The temperatures of the dried nimals remained at higher levels than those of the controls.

Both buffaloes and zebu cows were used in studies to determine the effects of walking before, during or after the shower. Two animals of a species were used in each test. The procedure was that for one-half of every 15 minutes during the shower or drying period one of the pair was exercised at the walk in the open air and then brought back to the shed. During these $7\frac{1}{2}$ minutes, buffaloes walked about 400 and cows 600 feet. Exercising before the shower was also at the walk, for one hour sometime between 3 and 5 P.M. and for about $1\frac{1}{2}$ miles, when the animals were at once put under the shower. During each experimental period of four days, the first and third were as usual "dry" days, the second and fourth "wet." The one animal was exercised on all four days, the other being the control at rest. After a few days interval this routine was repeated, using the same two animals, but reversing treatments. "Heavy rain" was given for two hours, followed by a 4-hour drying period. While the one animal was being exercised, the shower was turned off so that the duration of shower was the same for both animals. It was observed that slight exercise during the shower maintains or may even increase the body temperature, although this effect may not be at once apparent. Similarly, exercise during drying will speed up the return of body temperature to normal. Exercise during both shower and drying is still more beneficial.

Experiments with Natural Rain

Vittoz and Nguyem-Ngoc-Minh (1939) in Cochin China record mean falls of body temperature of 1.8° and 0.97° F. in adult buffaloes and oxen, respectively, immediately after showers of rain. Shade temperature was 54° F. No other details are given.

Observations were made on buffaloes at Izatnagar and on hill-bulls and sheep at Mukteswar. Groups of animals up to 10 or 12 in number were kept

in readiness during the rainy season and their temperatures recorded just before exposure to rain. After the rain had ceased, they were allowed to dry naturally in the open in a sheltered place. Unless otherwise stated, the animals were tethered. The results of twenty observations with monsoon rain are summarized in table 2. These indicate that in buffaloes at Izatnagar and in hill cattle and sheep at Mukteswar there is considerable variation in the mean maximum fall of body temperature due to rain. The 't' test shows that in most cases the fall is highly significant, though the extent of the fall is not clearly related to the degree of exposure. No ill effects were

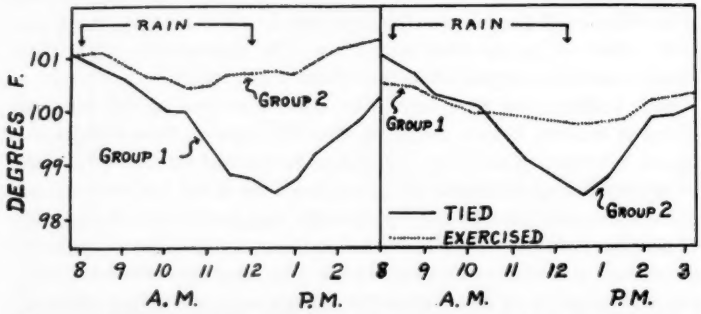

Figure 3. Effects of natural rain on the body temperature of two groups of water buffaloes when tied and being exercised 15 minutes in every 30. The first test (left) was conducted on August 13, with air temperature of 79–80° F. and rainfall of 1.03 inches. The second test was made on August 15, with air temperature of 80–82° F. and rainfall of 1.15 inches. Rain water temperature was 75° F.

shown by the animals after they had dried off. Sample results are given in figures 3 and 4. Observation 7 of table 2 and figure 3 illustrate the beneficial effect of a little exercise during the rain, the differences in this respect between exercised and tied animals being highly significant.

Observation 7 in table 2 summarizes the results of a reversal experiment. The animals in 7 (a) are the same as those in 7 (c), while those in 7 (b) and 7 (d) are the same. The differences in fall of temperature between 7 (a) and 7 (b) and between 7 (c) and 7 (d) were 1.95 and 1.92° F., respectively, and show the benefit of walking upon maintenance of body temperature during rain.

Some data were obtained on the temperature of rain water at Mukteswar and Izatnagar at altitudes of 7,500 and 570 feet, respectively. Twenty-one observations at Mukteswar between July 1 and September 18 ranged from 57 to 67, and averaged 61° F. At Izatnagar 3 observations were made in December, 11 in January and 43 in July and August. The respective ranges in degrees F. were 61–62, 48–59 and 75–82, with averages of 61.5, 52 and 78.

Experiments on Wallowing, Hosing and Splashing of Water Buffaloes

Water buffaloes must be protected from prolonged exposure to direct sunlight in summer in order to preserve health and milk production. In practice, it is also considered indispensable that they should wallow daily in water during the hot months. If no pond or tank is available, it is customary to splash water over them by hand or with a bucket.

The inclination of buffaloes to wallow at different seasons was studied at Izatnagar from December, 1943 to December, 1944. Nineteen observa-

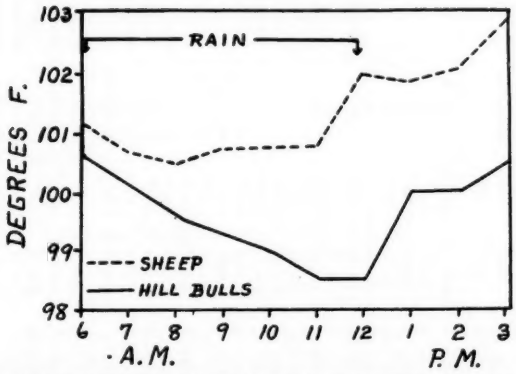

Figure 4. Effects of natural rain on the body temperature of sheep and cattle (small hill bulls). Ten animals of each type were used, and the curves are based on the mean of each group. Data were taken on July 2, when average air temperature was 58.7° F., and the rainfall was 2.94 inches.

tions were made, using 31 male buffaloes aged about 6–8 years, *viz.*, fourteen up to March in groups of seven, and seventeen others after that month in groups of ten. The average body weight of each group was usually from 700 to 800 lbs. The animals were habitually sent out for grazing from 7:00 to 10:00 or 11:00 A.M. when they were brought into a shed. From April onwards, they had free access to water during the grazing period. On days selected as representative of the season, but not on rainy days, the buffaloes were given walking exercise for an hour from 1:00–2:00 P.M., their temperatures being taken before and after. They were then liberated in a bunch close by the wallow, which was a natural tank with low banks and with water maintained at a depth of 1½ to 4 feet. The times of entering and leaving the tank were noted for every animal. The mean duration of the wallowing, the air temperature and humidity near the tank at the time of the observations, and the water temperature at 6 inches below the surface, are shown in figure 5. Average monthly variations in air temperature and rela-

TABLE 2. SUMMARY OF DATA ON THE EFFECT OF NATURAL RAIN ON THE BODY TEMPERATURES OF ANIMALS

Observation No.[1]	Date	Number and kind of animals	Rainfall			Average temperature before rain	Average maximum temperature fall[3]	Approximate air temperature	Notes
			Type or amount[2]	Water temp.[2]	Time				
			inches	*degrees F.*		*degrees F.*	*degrees F.*	*degrees F.*	
1	8-10-42	12 buffaloes	Slight	79	8:37- 10:20 A.M.	100.00	0.00	86	—
2	9- 2-42	12 buffaloes	Heavy	77	12:15-3:10 P.M.	100.42	0.68**	80	—
3	8- 4-43	9 buffaloes	0.60	77	11:30 A.M.-1:25 P.M.	101.32	1.27**	81	—
4	8 -5-43	9 buffaloes	1.10	77	7:15-11:30 A.M.	101.03	1.63**	77	—
5	8 -8-43	9 buffaloes	1.45	77	9:00 A.M.- 1:20 P.M.	101.04	0.91**	81	Grazing freely during rain
6	8 -9-43	9 buffaloes	0.75	77	12:20 M.-2:30 P.M.	101.08	1.32**	80	—
7 (a)	8-13-43	4 buffaloes	1.03	75	8:00 A.M.-12:50 P.M.	101.13	2.58**	—	Tethered during rain
(b)	8-13-43	4 buffaloes	1.03	75	8:00 A.M.-12:50 P.M.	101.15	0.63*	—	Walked 15 of every 30 minutes
(c)	8-15-43	4 buffaloes	1.15	75	7:15-11:15 A.M.	100.60	0.78*	—	Walked 15 of every 30 minutes
(d)	8-15-43	4 buffaloes	1.15	75	7:15-11:15 A.M.	101.15	2.70*	—	Tethered during rain
8	6-20-42	11 hill bulls	0.37	—	6:00-7:00 A.M.	101.07	0.55**	58.2-74.9	Body temperature recorded only just after rain
9	6-20-42	12 hill bulls	0.37	—	12:00 M.-12:50 P.M.	100.60	0.12	58.2-74.9	—
10	6-20-42	12 sheep (shorn)	0.37	—	6:00-7:00 A.M.	101.92	1.37**	58.2-74.9	—
11	6-20-42	12 sheep (shorn)	0.37	—	12:00 M.-12:50 P.M.	102.08	1.93**	58.2-74.9	—
12	6-23-42	12 hill bulls	2.18	—	5:00 A.M.-2:00 P.M.	101.15	3.87**	60.1-73.5	Maximum fall after 6 hours
13	6-23-42	12 sheep (shorn)	2.18	—	5:00 A.M.-2:00 P.M.	101.63	2.78**	60.1-73.5	Maximum fall after 6 hours
14	6-23-42	5 sheep (shorn)	2.18	—	6:30 A.M.-4:00 P.M.	103.12	2.04**	60.1-73.5	Maximum fall after 2-3 hours
15	6-23-42	5 crossbred cows	2.18	—	10:15 A.M.-1:15 P.M.	100.94	2.60**	60.1-73.5	Free in small yard. Readings just after rain only
16	6-23-42	5 hill cows	2.18	—	10:15 A.M.-1:15 P.M.	100.56	1.66**	60.1-73.5	Free in small yard. Readings just after rain only
17	7- 1-42	4 sheep (shorn)	3.10	—	6:00 A.M.-4:00 P.M.	102.60	1.00[4]	58.5-68.7	Maximum fall after 6 hours
18	7 -2-42	9 sheep	2.94	—	9:00 A.M.-5:00 P.M.	102.62	1.48**	58.5-68.7	Maximum fall after 6 hours
19	7 -2-42	10 hill bulls	2.94	—	6:00 A.M.-11:00 A.M.	101.12	2.60**	58.5-68.7	Maximum fall after 6 hours
20	7- 2-42	10 sheep	2.94	—	6:00-11:00 A.M.	101.42	0.86**	58.5-68.7	Maximum fall after 6 hours

[1] Observations 1 to 7 were made at Izatnagar; 8 to 20 at Mukteswar.

[2] Amount of rainfall at Mukteswar is that recorded at local station. Temperature of rainwater was not taken.

[3] If fall in temperature was significant, it is indicated by: *—significant; **—highly significant.

[4] Approached significance.

tive humidity approximated rather closely the curves in figure 5 for these factors at the times the animals were observed.

The water temperature at 18 inches below the surface was approximately 1.4° F. lower than that at 6 inches, while one observation showed that the temperature of the mud at the bottom was 5° lower still. The animals wallowed voluntarily from April to October, at other times they entered the water voluntarily for drinking or were pushed in but they did not lie down.

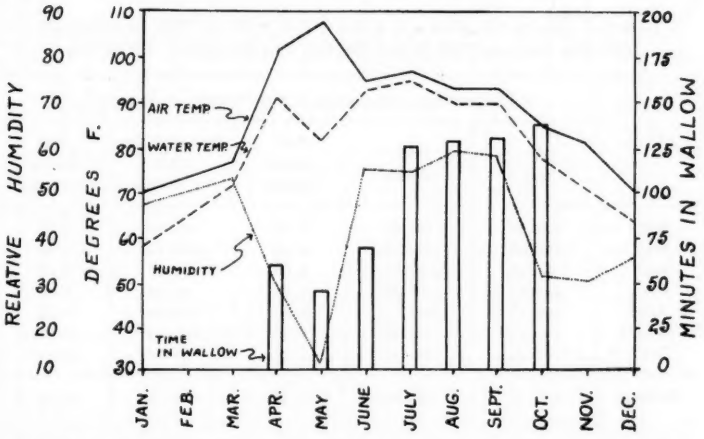

Figure 5. Incidence of natural wallowing by water buffaloes, by months, and month-to-month trends in some factors related to the incidence of wallowing. Based on observations during 1944. Ten animals were used.

It seems that there is a natural inclination to wallow when the air and water temperatures are above 85° and 77° F., respectively. The desire to wallow was intense during the hot damp months of August and September. At this season after an hour's walking exercise the animals were panting and seemed more tired than in May and June. In July–September the temperature rise on exercise and the fall on wallowing were greater than in the hot dry months of April–June. The observations on groups observed from April through October are summarized in table 3.

The animals tended to wallow in two phases; first they bunched together in the deeper water for a relatively short time of 15–30 minutes with their bodies wholly covered, they then distributed themselves over the more shallow parts where they remained for a longer time sitting with the lower part of the body partly immersed, occasionally dipping the head and rolling over to wet the exposed surface of the body.

During September when the weather was clear and sunny the animals were given an opportunity during seven consecutive days to wallow, not from 2:00 P.M. but from 8:00 A.M. They were brought to the tank and allowed to graze at liberty near by. The time of entering and leaving the wallow was noted for every animal until about 6:00 P.M. The daily maximum temperature near the tank was reached between 1:30 and 5:30 P.M. and ranged from 93 to 96° F. The mean relative humidity varied from 69 percent at 10:00 A.M. to 49 percent at 2:00 P.M. The mean maximum tem-

TABLE 3. MEAN TEMPERATURES OF GROUPS OF TEN BUFFALOES BEFORE AND AFTER WALLOWING IN DIFFERENT MONTHS

Month	Temperatures, and changes in temperatures, in degrees F.				
	At rest	After exercise	Rise during exercise	Immediately after wallowing	Fall during wallowing
Apr.	100.90	102.66	1.76	100.75	1.91
May	100.06	102.46	2.40	100.24	2.22
June	99.38	102.06	2.68	99.98	2.08
July	100.16	102.66	2.50	99.72	2.94
Aug.	100.58	102.86	2.28	100.22	2.64
Sept.	100.42	103.88	3.46	100.19	3.69
Oct.	99.31	101.58	2.27	98.81	2.77
Average	100.12	102.59	2.48	99.99	2.61

perature of the tank water was 91.6° F., and 89.6° F., respectively, at 6 and 18 inches below the surface. The animals appeared to behave more or less independently and no one animal played the part of leader. Their routine was similar every day. They generally entered the bath between 9:00 and 10:00 A.M., and lay down in the water for an average total period of 5½ to 6 hours. Frequently, some or all of them came out for grazing between 11:00 A.M. and 2:00 P.M., for an average time of 1½ hours, but varying considerably. On the seven days, the total period of bathing averaged roughly 8¼, 3, 7¾, 4½, 5, 6 and 5 hours. On the first day, seven of the buffaloes stayed in the water continuously for some 8 hours. During the second wallow on one day the animals kept to the more shallow parts.

Other observations on the cooling of water buffaloes are summarized in table 4. It is seen that after buffaloes have been warmed up by grazing in the sun or by forced walking exercise, wallowing for periods satisfying to the animal may bring the body temperature down by 3 to 4° F. Incidentally, as would be expected, their respiration rate is also greatly reduced. Buffaloes which are tied in the shade after being warmed up and not permitted to

TABLE 4. SUMMARY OF DATA OBTAINED IN VARIOUS TESTS OF THE COOLING OF WATER BUFFALOES

Observation No.[1]	Date	Method of cooling	Number of animals	Approximate air temperature	Duration of exposure		Time and temperature before cooling		Average maximum fall[2]	Notes
					Range	Average	Time	Temperature		
				degrees F.	*Minutes*	*Minutes*		*degrees F.*	*degrees F.*	
1	7-28-42	Wallowing	12	100	42–102	75	3 P.M.	102.76	1.43	Grazing in sun 1 hour before
2	9-17-42	Wallowing	12	94	29–70	55	4 P.M.	102.67	1.93	Grazing in sun 1 hour before
3	10-13-43	Wallowing	9	87	—	245	11 A.M.	101.66	4.49	Grazing in sun 4 hours before
4	10-14-43	Wallowing	8	86	—	195	11 A.M.	102.18	3.58	Grazing in sun 4 hours before
5	10-15-43	Wallowing	8	87	—	185	11 A.M.	102.30	3.43	Grazing in sun 4 hours before
6	10-16-43	Wallowing	7	87	—	220	11 A.M.	102.09	3.89	Grazing in sun 4 hours before
7	10-18-43	Wallowing	8	86	—	175	11 A.M.	102.40	3.66	Grazing in sun 4 hours before
8	9-28-43	Wallowing	7	82	12–86	60	9 A.M.	100.20	1.20	Animals forced into tank
9	9-29-42	Wallowing	7	79	57–132	97	9 A.M.	99.99	0.69	Animals forced into tank
10	10-4-42	Wallowing	12	80	9–53	20	9 A.M.	100.49	1.43	Animals forced into tank
11 (a)	9-19-43	Wallowing	4	91	—	115	11:30 A.M.	101.88	3.18	Exercised 1 hour in sun, then forced into tank
(b)	9-19-43	Wallowing	4	91	—	115	11:30 A.M.	101.80	0.85	Exercised 1 hour in sun before. No wallow
(c)	9-21-43	Wallowing	4	90	—	115	11:30 A.M.	102.60	1.43	Exercised 1 hour in sun, before. No wallow
(d)	9-21-43	Wallowing	4	90	—	165	11:30 A.M.	102.58	3.15	Exercised 1 hour in sun, then forced into tank
12 (a)	6-14-44	Wallowing	10	105	—	20	1:00–2:00 P.M.	103.34	3.61	One hour walk in sun before
(b)	6-15-44	Splashing	10	102	—	10	1:00–2:00 P.M.	102.82	2.57	One hour walk in sun before
(c)	6-16-44	Hosing	10	105	—	3	1:00–2:00 P.M.	103.32	2.94	One hour walk in sun before
(d)	6-17-44	Wallowing	10	103	—	61	1:00–2:00 P.M.	102.70	4.21	Allowed to wallow as long as desired.
13	5-18-45	Hosing	10	96	—	3	3:00 P.M.	101.68	2.64	One hour free walking and grazing before. After shower left free in shed of which approximate temperature is shown
	5-19-45	Hosing	10	98	—	3	3:00 P.M.	101.27	1.55	
	5-20-45	Hosing	10	99	—	3	3:00 P.M.	101.68	2.11	
	5-21-45	Hosing	10	100	—	3	3:00 P.M.	101.69	1.95	
	5-22-45	Hosing	10	103	—	3	3:00 P.M.	101.50	1.54	
	5-23-45	Hosing	10	102	—	3	3:00 P.M.	101.44	1.62	
	5-25-45	Hosing	10	103	—	3	3:00 P.M.	101.65	1.46	

[1] Observations 1 to 11 were made at Izatnagar, 12 at Lahore, and 13 at Bareilly.

[2] All the falls in temperature were highly significant.

wallow, show decreases of about 1° F. If buffaloes are forced into the tank as early as 9:00 A.M. and without being exercised, they show reduction of 0.7 to 1.4° F. All these falls are highly significant.

An observation made at Lahore (Punjáb) in February 1945, showed that 38 buffaloes packed in a wallow for 40 minutes scarcely raised the temperature of the water (water temperature was 83° F., air temperature was 66° F.).

Observation No. 11 in table 4 is a summary of a reversal experiment. The same animals were used in 11(a) and 11(c), and another group was used in 11(b) and 11(d). The average differences in temperature drop between 11(a) and (b) and between 11(c) and (d), respectively, were 2.33° and 1.72° F. Both were highly significant and show the effect of wallowing in reducing body temperature after exercise.

Wallowing for a period restricted to 20 minutes may bring the temperature down by about 3° F. in the exercised animal and a similar effect may be produced by hosing the body for 3 minutes. Hand splashing for 10 minutes is nearly as good. Buffaloes readily lie down in shallow water, say 2 or 3 inches, and this within 2 hours was found to reduce the mean temperature by 1 or 2° F.

Results of a comparative experiment are shown as observation 12 in table 4. The differences between various treatments are summarized below:

Groups compared	*Difference, °F.*	*Significance of difference*
(a) and (b)	1.04	Significant
(a) and (c)	.67	Not significant
(a) and (d)	.60	Not significant
(b) and (c)	.37	Not significant
(b) and (d)	1.64	Highly significant
(c) and (d)	1.27	Highly significant

Thus, it may be seen that there is no significant difference between wallowing for 20 minutes (group a) and one hour (d), or between hosing for 3 minutes (c) and splashing for 10 minutes (b). On the other hand, there is a highly significant difference between wallowing for one hour (d) and hosing (c) or splashing (b), and there is a greater drop in temperature due to wallowing for 20 minutes (a) than splashing for 10 minutes (b).

On each of seven days, a group of ten buffalo cows (mean weight, 1087 lbs.) were subjected for 3 minutes at 3:00 P.M. to a shower (water temperature about 85° F.), delivered from a metal pipe of 1½ inch bore with the partly closed opening directed upwards so that the heavy spray (on an average 1.31 inches of rain in the three minutes) fell on the animals. Before this, the animals had been allowed to walk and graze freely in a paddock for an hour, and immediately after the shower they were left to roam at will in a large

milking shed. Body temperatures were taken before entering the paddock, immediately before and after the shower, and twice more at intervals of 30 minutes during the drying period. The results, given as observation 13 in table 4, show that there was a mean fall of about 1.8° F., which in fact brought the temperature back to its original level. During the drying period the animals usually stood for a time, occasionally moving about in search of food or rubbing against some hard object, and within an hour they lay down and ruminated.

Discussion and Application of Results

The results emphasize the inefficiency of temperature control of the buffalo compared with the zebu cow. This is in conformity with the much wider range of rectal temperatures of the resting buffalo compared with that of the cow (Minett and Sen, 1945). The difference may be due in part to the heavy coat of the cow preventing intimate wetting of the skin but more likely to the thyroid-adrenal mechanism being less efficient in the buffalo.

The artificial showers used in this work have served to illustrate general principles. However, water falling almost vertically and in continuous streams from a spray nozzle does not simulate natural rain, where water falls in drops, is intermittent and variable in force, and is often accompanied by wind liable to frequent change of direction and velocity. Moreover, the effect of a natural shower is to cool the air at least temporarily and to raise its humidity, so that the process of drying-off is retarded.

A factor which may be important in nature is the temperature of the falling rain and some data have been collected on this point. The matter has been dealt with by Das (1933) who also cites the findings of others. The general conclusion is that the temperature of rain is slightly lower than that of the air, it approximates in fact to the wet-bulb temperature. In most cases the difference would not exceed 3° C. and would often be considerably less. The temperatures of rain associated with thunder storms will tend to be lower, while if the rain is accompanied by hail and snow it can sometimes be very low. In India, a relatively low rain temperature is likely to be operative only in the north-western areas and in the months of January, February and December.

Animals which wallow have semi-hairless skins, *e.g.*, buffalo, pig, hippopotamus. The inclination to wallow is probably governed by several factors, apart from the main one which is the desire to cool an overheated body, such as habit, bodily condition, and the management routine to which the animal is accustomed. At certain of the Military Farms in northern India, *pukka* wallows are provided in the form of cement tanks, 4 feet deep to hold about 3 feet of water. Their sizes vary from 30 feet square, taking about

fifty buffaloes, to ones 84×80 feet taking 250–300 buffaloes closely packed together. At the Lahore Military Farm, buffaloes wallow for one hour twice daily, midday and midnight (at midday only in winter), and for an hour before milking in the case of females. The water comes from tube-wells, and since even in winter its temperature is not less than 70° F., the animals bathe readily. During wallowing, it is usual for an attendant to splash the animals' bodies with water from a bucket. Without wallowing or body-washing, a buffalo's daily milk yield might be expected to fall by at least a pound. Calves over six months are also allowed to wallow; below this age and during the hot weather their bodies are merely splashed. One disadvantage is that the wallow water becomes grossly fouled by excreta, in spite of its being changed every day or two. In spite also of the udder and teats being washed before milking, this may lead to trouble with the milk, which will give a shortened reduction time by the methylene blue test. Thus, from the point of view of milk quality it is preferable to pour water over the buffaloes, as is done when no tank is available, more however with the idea of cleaning than cooling them. Also, wallows are costly to build, and in fact the Military Farms are so longer constructing them. In organized dairies it would be equally effective and far more hygienic if buffaloes were subjected to a shower bath once or twice daily. Similar treatment might be advantageous for high-grade European crossbred cows, in addition to periodical clipping of the coat which is now commonly done on Military Farms during the hot weather.

Summary

Experiments were conducted to determine the effects on body temperature of artificial and natural rain in water buffaloes, zebu cattle small hill cattle and sheep, and the effects of wallowing, hosing and splashing in water buffaloes.

A heavy shower for two hours will lower the body temperature of buffaloes by 2.8° F. in the morning and 1.6° F. in the afternoon, on the average, while a similar shower will reduce temperature of zebu cows by only 0.5° F in the afternoon. Young buffaloes are especially susceptible to the effects of rain on body temperature. With buffaloes, the fall is mainly during the shower, while with cattle it is due to the drying-off period.

Mean body temperature decreases of about 0.7° to 2.7° F. as a result of natural rain, have been noted during the summer monsoon at Izatnagar, and of 1.6° to 3.8° F. in hill cattle and 1.4° to 2.7° F. in sheep, standing in monsoon rain at Mukteswar.

The fall in body temperature due to rainfall can be counteracted by light exercise during the shower or drying-off period, or both. Rough drying fol-

lowing the shower is also beneficial. Adult water buffaloes wallowed naturally from April to October, when air and water temperatures were above 85° and 77° F., respectively. Desire to wallow was most intense from July to October.

Various methods of cooling water buffaloes were tested. Wallowing for 20 minutes and one hour gave similar results. Hosing for 3 minutes was as effective as wallowing for 20 minutes, while splashing for 10 minutes was not quite as good. Wallowing by the previously-exercised animal will reduce the temperature by as much as 3° to 4° F.

In organized dairies, a shower bath should be practically as efficacious, more hygienic, and no more costly than a properly-constructed wallow.

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CAROTENE BLOOD LEVELS AND REPRODUCTIVE PERFORMANCE IN RANGE HEREFORD CATTLE[1]

MERLE G. PAYNE AND H. E. KINGMAN[2]
Colorado Agricultural Experiment Station

THE work of various investigators has suggested that in cattle there is a relationship between the carotene blood level and health and between the carotene blood level and reproduction, and that these levels vary with the age and breed of animal and type of feed.

The study here presented was undertaken to determine carotene levels necessary for health and reproduction among range Hereford heifers and aged cows.

Review of Literature

A blood-plasma level of carotene adequate for health was reported by Davis and Madsen (1941) in work with Hereford and Shorthorn heifers to be 25 micrograms per 100 milliliters of blood plasma. These results are essentially in agreement with those of Moore (1939), who worked with Holstein and Ayrshire calves and reported that a plasma carotene of 0.2 micrograms per 1 milliliter or above was sufficient to maintain fair general health. Both of these results are in agreement with the work of Kuhlman and Gallup (1942) on Jersey calves. Boyer *et al.* (1942) set, as normal requirements for health, carotene blood levels of 50–70 micrograms per 100 milliliters for Holstein yearlings and 110–140 micrograms per 100 milliliters for Guernsey yearlings.

Davis and Madsen (1941) and Kuhlman and Gallup (1942) reported the blood level necessary for normal reproduction was 78–96 micrograms per 100 milliliters of plasma and 81–150 micrograms per 100 milliliters of plasma, respectively. These indicate that the level adequate for normal reproduction was higher than the level they reported adequate for health.

Davis and Madsen (1941) reported that an inadequate carotene intake in cattle could be determined by blood analysis. The carotene and vitamin A content of blood plasma at any particular time was dependent on the current intake and previous storage of these factors. When cattle were depleted of carotene reserves, the blood carotene level was dependent on intake alone. Vitamin A values tended to reach a stable level and did not increase proportionally with intake as did the carotene level.

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[2] Associate Chemist, Colorado Agricultural Experiment Station; Veterinarian, Wyoming Hereford Ranch Trust, Cheyenne, Wyoming, respectively.

Braun (1945) stated that changes in the carotenoid blood level were mainly dependent on the carotene intake but varied according to the age and breed of animal. Essentially the same results were reported by Kuhlman and Gallup (1942). Braun also analyzed the relation of carotenoids to vitamin A in the blood. An increase of vitamin A with increasing carotenoid levels was found and the ratio of vitamin A to carotenoids at various carotenoid levels was established. This ratio was found to decrease with increasing carotenoid levels, and reached a constant value at high carotenoid levels. The ratio was below normal in cases of physiological disturbances (parturition, abortion, and acute infections), above normal if the animals were subject to decreasing carotenoid intake, and well above normal if a vitamin A supplement was fed.

Materials and Methods

A large group of Hereford cattle running in a Wyoming pasture was used in this study. The pasture lies east of the Rocky Mountains at an altitude of 6000 to 7000 feet above sea level. The forage was composed chiefly of blue grama, buffalo grass, wheat grass, and needle grass. The comparatively uniform altitude, topography, and flora of this area are important since it is recognized that carotene content of forage varies with the species, with composition of the soil, and with the growing season.

The cattle were separated in the pasture in both 1943–44 and 1944–45 so that the heifers (142 head) were pastured away from the main breeding herd (750 head). The heifers were hand bred during the summer months while running in a 3500-acre pasture. They were moved in late fall to meadow pasture and then were brought into lots for supplemental feeding in March. The main breeding herd, running in a 50,000-acre pasture, subsisted from seven to twelve months of the year on the available pasture plants and received supplemental feed only during the winter months (usually January, February, and March).

The carotene content of the range forage was not determined. Unless the investigator doing the sampling was very familiar with the range and grazing habits of the cattle, it would be difficult to sample accurately the forage consumed from such a large range. Hence the evaluation of carotene intake was not practical in these studies.

The blood-plasma level was used in studying adequate carotene for health and reproduction. Blood samples for analysis of carotene content were taken in connection with the routine care of the herd at such times as when the cattle were being run through the chutes for change of pasture, branding, spraying, for Bang's disease, etc.

For the years studied approximately 75 percent of the blood samples for

the aged cow and heifer groups were taken in November. The remainder of the samples were divided about equally between January and March.

Venous blood was drawn from the jugular vein. Lithium oxalate (1.5 to 2 mg. per milliliter of blood) was used as the anti-coagulant and the plasma was separated by centrifuging. Depending on the amount of carotene present, samples for the determination varied from 10 to 20 milliliters of blood plasma. The carotene values were expressed in terms of micrograms per 100 milliliters of blood plasma. The procedure used was that of Madsen and Davis (1939) adapted to the Coleman spectrophotometer. The percentage transmission was determined at a wave length of 450 millimicrons.

Only apparatus with ground-glass stoppers and stopcocks was used since considerable material may be dissolved from rubber connections and stopcock grease which would interfere with the determinations. Special care was taken to purify all reagents used and to carry through the determinations as rapidly as possible. A total of 125 determinations was made.

Experimental Data

The carotene blood levels necessary to prevent deficiency symptoms, and those adequate for reproduction, vary with the age and breed of animal

TABLE 1. THE CAROTENE BLOOD-PLASMA LEVEL FOR AGED COWS AND HEIFERS EXPRESSED AS MICROGRAMS OF CAROTENE PER 100 ML.

Items compared	Aged cows		Heifers	
	1943–44	1944–45	1943–44	1944–45
Mean blood-plasma level, micrograms 100 ml.	82.88	95.62	117.75	97.18*
Standard error of an individual observation	26.01	31.82	24.99	36.79
Standard error of a corresponding mean	4.11	4.50	7.21	7.68
Number of animals comprising the sample	40	50	12	23

* 97.18 micrograms/100 ml. is not adequate for normal reproduction in heifers.

and type of feed. In the work that follows these factors were taken into consideration on range Hereford cattle raised in the same geographical location and of similar breeding.

The statistical studies of the carotene blood-plasma levels during the years 1943–44 and 1944–45 for the heifers and main breeding herd are presented in table 1.

The data presented in table 1 show that the carotene blood-plasma level

for 40 aged cows in 1943–44 was 82.88 micrograms per 100 ml. ± 4.11; for a different group of 50 aged cows in 1944–45, it was 95.62 micrograms per 100 ml. ± 4.50. The difference in the two groups was 12.74 micrograms per 100 ml. and was significant since the ratio of the difference to the standard error of the difference was 2.09. The odds of significance were 24:1. The fact that there was a significant difference in the two groups of aged cows in 1943–44 and 1944–45 was possibly due to the better growing conditions for grass in the summer of 1944–45 during the month of June.[3] In both years the carotene level for aged cows was adequate for health and reproduction since there was no clinical evidence of a carotene deficiency. However, animals may suffer a borderline deficiency of carotene without showing any of the classic symptoms.

In 1944–45 a check on the carotene blood-plasma level was made in March and April on small groups picked at random from the main breeding herd of about 750 animals. The average carotene blood-plasma level for 10 cows in March was 70.7 micrograms per 100 ml., and for 7 cows in April it was 83.5 micrograms per 100 ml. The groups were too small to indicate more than a possible trend. This upward trend in April possibly was due to small amounts of early green pasture, which was needle grass.

The carotene blood-plasma level for the 12 heifers in 1943–44 was 117.75 micrograms per 100 ml. ± 7.21; for a different group of 23 heifers in 1944–45 it was 97.18 micrograms per 100 ml. ± 7.68. The difference in the means was 20.57 micrograms per 100 ml. This was a significant difference since the ratio of this difference to the standard error of the difference was 2.04. The odds of significance were 23:1. The difference in the carotene blood-plasma level for two years in the heifer group probably was due to the difference in the supplemental feed. The hay and alfalfa in 1943–44 were of better grades; that is, they were greener than in 1944–45. Hart and Guilbert (1933) have shown that carotene potency of hay is closely associated with degree of green color.

In the 1943–44 heifer group there was no clinical evidence of a carotene deficiency with the exception of a few retained placentas. In the 1944–45 group there were retained placentas and 11 abortions. In the group of 142 heifers, of which the 23 in 1944–45 were only a sample, there were 31 abortions.

There is a difference in the carotene requirements of first-calf heifers and aged cows. For instance, it required 117.75 ± 7.21 micrograms of carotene per

[3] Official weather bureau records at the Archer Field Station, Archer, Wyoming located 10 miles northeast of the experimental area, show that the total precipitation for June through September 1943 was 7.64 inches with a positive departure of 0.32 inches. During the same period in 1944 the total was 7.54 inches with a positive departure of 0.25 inches. The two years were similar in monthly distribution except that the total positive departure in June 1944 was 1.48 inches as against 0.56 inches in June 1943.

100 ml. of blood plasma for health and reproduction in heifers and only 82.88 ± 4.11 micrograms of carotene per 100 ml. of blood plasma for aged cows. The difference in the means was 34.62 micrograms per 100 ml. This was a significant difference, since the ratio of this difference to the standard error of the difference is 4.17. The odds of significance were 17,000:1. Furthermore, when the carotene blood-plasma level was reduced to 97.18 ± 7.68 micrograms per 100 ml. in 1944–45 retained placentas and abortions resulted. A possible explanation of the difference in carotene requirements of first-calf heifers and aged cows is that the heifers required additional carotene for growth. The abortions in the 1944–45 heifer group were not caused by the presence of *Brucella abortus*, *Trichomonas foetus*, or *Corynebacterium pyogenes*, since tests for these organisms were uniformly negative. Therefore, the abortions were believed to be related to low carotene blood levels. The heifers that aborted showed edema of fetal membranes, cotyledons, and uterine wall. This condition is associated with a carotene deficiency. It is also associated with an infection due to the malignant edema group of organisms, although these are seldom identified as the cause of abortion. Since the genital tract during parturition offers an ideal condition for infection, this group in our opinion has not been entirely eliminated as a cause, with the exception of *Corynebacterium pyogenes*.

These results are in partial agreement with those of Kuhlman and Gallup (1942) who reported that first-calf Jersey heifers require 150 micrograms of carotene per 100 ml. of blood plasma and aged cows 81–150 micrograms of carotene per 100 ml. of blood plasma. This shows a higher blood-plasma level for the heifers than for the aged cows. However, the level for Jersey heifers was somewhat higher than was needed for the first-calf range Hereford heifers. The level for aged cows compared rather well with the results of Kuhlman and Gallup (1942).

Davis and Madsen (1941) in their work with Shorthorn and Hereford heifers in feed lots found a blood-plasma carotene level of 78–96 micrograms per 100 ml. was necessary for gestation. The results in this work for range Herefore heifers were somewhat higher, although the results for the range Hereford aged cows were similar

This study indicates that the blood-plasma carotene level for first-calf range Hereford heifers should be at least 117.75 ± 7.21 micrograms per 100 ml. of blood plasma for normal gestation, since this level during the year 1943–44 resulted in an approximately normal reproduction situation.

Summary

In order to support normal gestation the carotene blood-plasma level of first-calf range Hereford heifers must be considerably higher than that for aged Hereford cows.

The results indicate that the carotene blood-plasma level of first-calf range Hereford heifers must be at least 117.75 ± 7.21 micrograms per 100 ml. in order to support normal gestation.

Range Hereford heifers with carotene blood plasma level of 97.18 ± 7.68 micrograms per 100 ml. showed clinical symptoms of a carotene deficiency, so-called nutritional abortions, and cases of retained placentas.

A breeding herd of range Hereford aged cows with an average carotene blood-plasma level as low as 82.88 ± 4.11 micrograms per 100 ml. showed no clinical symptoms of a carotene deficiency and no so-called nutritional abortions over a two-year period. Therefore, such a carotene blood-plasma level may be considered adequate for health and reproduction for range Hereford aged cows in this area.

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THE RELATIVE ACCURACY OF ONE-DAY AND THREE-DAY WEANING WEIGHTS OF CALVES

A. L. Baker, Ralph W. Phillips and W. H. Black
United States Department of Agriculture[1]

THE practice of weighing animals on three consecutive days, at the beginning and ending of experimental trials, is generally followed in animal husbandry research, but a recent study by Bean (1946) has indicated that the taking of 3-day weights of swine is not justified. Lush and Black (1926) and Lush *et al.* (1928) have studied the relative accuracy of single and multiple weights of beef cattle. They conclude that weighing for two additional days eliminates about 42 percent of the error contained in a one-day weight. In the latter paper it is pointed out that the standard deviation in the accuracy of single weights may be expected ordinarily, under uniform conditions, to be between 6 and 12 pounds, that the standard deviation is somewhat smaller in younger cattle and is distinctly smaller under unchanging environmental conditions, than when a sudden change is made in some important condition between the two weighings.

Under certain conditions, there may not be any increase in accuracy as a result of multiple weighings of cattle. This is indicated by the results of a study of weaning weights presented in this paper.

Material and Methods

The weaning weights used in this study were obtained on 178 calves during 1943–4–5, at the Iberia Livestock Experiment Farm, Jeanerette, La. Of these, 91 heifers and 51 steers were zebu-Angus hybrids carrying $\frac{1}{4}$, $\frac{3}{8}$ or $\frac{1}{2}$ zebu blood; and 19 heifers and 17 steers were of Africander-Angus breeding with $\frac{1}{4}$, $\frac{3}{8}$ or $\frac{1}{2}$ Africander blood. The calves ranged in age from 177 to 283 days, and averaged about 232 days when weighed. Male calves had been castrated at about 140 days of age. The calves were not weaned until immediately after the third weight was obtained, and had been kept with their dams on pasture up to weaning time.

The calves and their dams were moved to a pasture within $\frac{1}{4}$ mile of the scale on the day preceding the first weighing, and were kept there until weighings were completed, except for movements to and from the scales. Weighing operations began between 6:00 and 6:30 A.M., and continued until completed, regardless of weather conditions. The calves were weighed in as nearly the same order as possible each day, and every effort was made to avoid undue excitement.

[1] Iberia Livestock Experiment Farm, Jeanerette, La. and Agricultural Research Center, Beltsville, Md. The authors are indebted to G. A. Fortier, Agricultural Aide, who obtained the weights used in this study.

Weights were taken on a 10-ton double-beam pit scale with a platform that measured $10\frac{1}{2} \times 22$ feet. It was mounted in concrete and housed under a shed. Weights were taken to the nearest 5 pounds. Care was taken to keep the scale in balance at all times and all weights were taken by the same technician.

Data were analyzed according to the procedures used by Bean (1946).

Data and Discussion

A summary of the results is given in table 1.

TABLE 1. COMPARISON OF WEIGHTS OF CALVES OBTAINED ON 3 CONSECUTIVE DAYS WITH THE 3-DAY AVERAGE WEIGHTS, THE DATA BEING GROUPED BY 20-POUND INTERVALS

Weight interval (pounds)	No. of calves	1st-day weights (pounds)	2nd-day weights (pounds)	3rd-day weights (pounds)	3-day average (pounds)	All weights (pounds)	Standard error of 3 times the 1st-day weights
280–299	4	287.5±3.23	287.5±4.33	288.8±4.27	287.5±3.54	287.9±1.21	1.86
300–319	4	307.5±1.45	307.5±4.33	306.2±2.40	307.0±2.16	307.1± .90	.84
320–339	6	329.2±1.54	330.0±1.82	326.7±2.47	328.5±1.61	328.6± .65	.84
340–359	17	348.6±1.03	349.8±1.57	344.7±1.63	347.6±1.15	347.6± .50	.59
360–379	10	369.0±1.63	366.5±3.34	365.5±2.29	366.9±2.18	367.0± .83	.94
380–399	18	386.4±1.50	384.4±2.32	382.2±2.37	384.2±1.94	384.4± .70	.87
400–419	18	406.9±1.35	405.6±2.49	406.7±2.02	406.5±1.77	406.4± .66	.78
420–439	23	428.5±1.19	427.6±1.75	427.2±2.35	427.7±1.66	427.8± .60	.69
440–459	19	445.5±1.07	445.2±1.93	441.6±2.13	444.1±1.52	444.1± .59	.62
460–479	21	466.4±1.34	465.0±1.92	458.6±3.35	463.4±1.91	463.3± .81	.77
480–499	12	486.7±1.78	486.2±2.15	488.7±2.89	487.3±2.04	487.2± .76	1.03
500–519	14	503.9±1.40	503.9±2.97	503.2±3.08	503.7±2.11	503.7± .85	.81
520–539	6	525.8±2.39	518.3±5.43	515.0±6.33	519.7±3.74	519.7±1.69	1.37
540–559	1	540.0	545.0	530.0	538.0	538.3±4.41	00
560–579	4	567.5±4.33	565.0±7.36	566.2±6.57	566.5±5.72	566.2±1.88	2.50
580–599	1	590.0	590.0	580.0	587.0	586.6±3.33	00
All groups	178	425.9±4.76	425.0±4.76	422.9±4.77	424.6±4.75	424.6±2.75	2.75

The mean weights on the 3 days show that, on the average, the calves lost a little weight during the 3 days of weighing operations. However, the 3-day average of 424.6 lbs. did not differ significantly from the average of 425.9 for the first-day weights. Inspection of gains and losses of individual animals showed that in the 3-day average compared with the first weight, 55 (or 30.9 percent) gained weight, 28 (or 15.7 percent) did not change, and 95 (or 53.4 percent) lost weight. Mean deviations in pounds in the various weight classes, including both plus and minus deviations, were as shown at the top of the next page.

The calves were classified into the groups on the basis of their first-day weights.

The relative dependability of weights on the 3 days, and the average of

Weight interval	Deviation	Weight interval	Deviation
280–299	2.76	460–479	5.47
300–319	2.00	480–499	2.50
320–339	1.33	500–519	4.64
340–359	3.06	520–539	7.17
360–379	2.50	540–559	2.00
380–399	3.33	560–579	5.50
400–419	3.11	580–599	3.00
420–439	3.17	600–619	0.00
440–459	3.42	All groups	3.58

those weights, may be assessed by comparing the standard errors. Taking the 420–439-pound group as an example, it may be seen from table 1 that the means and standard errors for the 1st, 2nd and 3rd weights and the 3-day average were 428.5 ± 1.19, 427.6 ± 1.75, 427.2 ± 2.35 and 427.7 ± 1.66. There is more variation, in this case, in the 2nd and 3rd-day weights, and in the 3-day average, than in the weights taken on the first day. Assuming that all these calves had weighed the same each day, the average would have been 428.5 ± 0.69 (standard error of 3 times first-day weights). If all the weighings were equally reliable, the standard errors for each should be approximately equal, and differences due to chance variation should occur at random. Thus, when comparing 1st-day and 3-day average weights, chance variations should result in a smaller standard error in each group an equal number of times. Actually, in the 14 weight classes having more than one animal each, the standard error of the 1st-day weights is less in every case than for the 3rd-day averages. Likewise, the standard errors of the 2nd and 3rd-day weights exceeded those of the 1st day, in all the 14 classes. The differences between the 2nd and 3rd days were not so marked, only 9 of the 14 standard errors being higher on the 3rd than on the 2nd day.

The weights used in this study were taken only to the nearest 5 pounds, owing to the type of scale available, and therefore lack something in precision, since Lush *et al.* (1928) have shown that some accuracy is gained by weighing to the nearest 2- rather than 5-pound interval, and a little additional accuracy is gained by weighing to the nearest pound, especially in small cattle. Therefore, some of the variation in actual weights of animals used in this study may not have been apparent, but this should not affect the validity of the comparisions of weights taken on different days and the 3-day averages.

The results summarized above indicate that there is no advantage, under the uniform conditions of this trial, in weighing calves on more than one day at weaning time.

Summary

A study of weights taken on 178 calves immediately before weaning time, when they averaged about 232 days of age, has shown that there was no advantage in taking weights on 3 days, over taking a single weight, when uniform conditions for the calves were maintained.

Calves lost some weight during the 3 days, the respective average daily weights being 425.9, 425.0 and 422.9. The 3-day average of 424.6 did not differ significantly from the weight taken on the first day.

After dividing into weight classes, with 20-pound intervals, the standard errors of single and 3-day weights were compared. In 14 classes having 4 to 23 animals each, the standard error was lower in the first-day weights in all classes than in the 2nd and 3rd-day weights and in the 3-day average. The standard error of the 2nd-day weights was lower than that of the 3rd-day weights in 9 of the 14 classes.

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EFFECT OF TECHNIQUES OF PREPARING SEMEN SMEARS FOR STAINING ON THE MORPHOLOGY OF BULL SPERMATOZOA

ERNEST MERCIER[1] AND G. W. SALISBURY

Cornell University[2]

DETERMINATION of the proportion of morphologically abnormal spermatozoa in stained semen smears was formerly considered as one of the best means of estimating the potential fertility of a breeding male (Williams and Savage, 1925; and Moench and Holt, 1931). More recently, the reliability of this method has been questioned (Dougherty and Ewalt, 1941; Herman and Swanson, 1941; and Lasley and Bogart, 1943). Little recent evidence has been obtained to show direct correlation between the proportion of abnormals and relative fertility in the bull (Trimberger and Davis, 1942; and Mercier, 1946) but no proof is yet available that abnormals need no longer be considered in routine semen examination. Direct evidence on this question is needed. Before sound evidence can be obtained easy and precise methods by which the proportion of abnormal spermatozoa in bull semen can be determined routinely in any laboratory need to be developed.

Work in this laboratory revealed that the procedures used in preparing smears for staining might have an influence on the proportion of tailless heads and abnormally-formed spermatozoa observed. Also, evidence was obtained suggesting that in fertile semen the true relationship between abnormals and relative fertility might be obscured by considering the tailless spermatozoa as abnormals (Salisbury *et al.*, 1942; and Mercier, 1944, 1946).

On the other hand, experience of the authors and others has shown that one of the changes accompanying seminal degeneration, whether caused by nutritional deficiencies (Cunningham and Hopkirk, 1935), extreme changes of temperature of the testes (Chang, 1943), or some pathological disturbance (Williams and Savage, 1925), is the appearance of tailless spermatozoa in the semen.

These facts suggested a need for further investigation of the methods of preparing smears for staining in order to differentiate the tailless heads produced in the male genital tract and those artificially made.

Thus, three experiments were carried out to study the effects of the methods used in making, clearing and staining smears on the proportion of tailless heads and on the proportion of abnormally-formed spermatozoa in fresh and stored semen of fertile bulls.

[1] The data contained in this report are from a thesis presented by Ernest Mercier to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1946.

[2] Laboratory of Animal Breeding and Artificial Insemination, Department of Animal Husbandry, Cornell University, Ithaca, New York.

Experimental Procedures and Results

The two methods of making smears compared in this paper are referred to as the "pulling" and the "drop" methods. They are methods 1 and 4 described by Salisbury *et al.* (1942). In this study 0.1 ml. of semen was mixed gently with 1.0 ml. of a 3.6 percent solution of $Na_3C_6H_5O_7.2H_2O$, and used for every smear. For semen stored at room temperature sulfanilamide was added at the rate of 300 mg. per 100 ml. of the citrate buffer to prevent bacterial growth (Knodt and Salisbury, 1946).

The smears, when cleared, were immersed in a 1.0 percent solution of chlorazene and then stained by the methods previously described by Salisbury *et al.* (1942), though the order of staining was reversed (Mercier, 1944). Only 100 spermatozoa were examined on each smear (Salisbury and Mercier, 1945), and the morphological abnormalities recorded according to the classification followed by Mercier (1944). All the tailless sperm were recorded separately and only the abnormally-formed tailless heads were included in the number of true abnormals.

The data of each experiment were analyzed by the method of analysis of variance as described by Snedecor (1946).

Experiment 1, Fixing of Smears

In order to study the effect of fixation by heat or albumin on the results obtained with the two methods of making smears with fresh or stored semen the first experiment was conducted. Four ejaculates were mixed and diluted with citrate buffer containing sulfanilamide. Of the 48 smears made with a part of this sample on the day of collection, 4 of them (two made by each method, one with and the other without albumin) were not heated. Five groups of 4 smears each were heated immediately on a slide warmer at a temperature of 36.5° C. for a period of 2, 4, 8, 16 and 32 hours, respectively. The remaining 24 smears were given the same heat treatment 24 hours after having been made. The other part of the diluted sample was stored at room temperature for a period of 4 days and used to replicate the first part of the experiment. Five days later, the 96 smears were cleared and stained in a home made 100-slide rack for the purpose of standardizing as much as possible the staining procedure. They were examined three days later. The pertinent data are presented in table 1.

The use of albumin fixative and the heating of smears either immediately or 24 hours after they were made did not influence significantly the proportions of tailless heads and abnormals. Therefore, the data are not presented separately for these two items. Similarly, the length of time smears were heated did not affect the morphology of spermatozoa.

Highly significant differences between methods occurred with respect to

the tailless heads and the abnormals. These results agree with those obtained by Salisbury *et al.* (1942) and by Mercier (1946) and, as discussed later, were believed to be due to a difference in the thickness of the smears. In this study the smears made by the pulling method were much thinner than those made by the drop method, because a part of the 1.0 ml. of diluted semen used for each smear was squeezed out when the upper slide was put on the bottom slide and both pulled apart lengthwise.

More tailless heads were found in smears made with fresh than with

TABLE 1. EFFECT OF METHODS OF MAKING AND HEATING SMEARS ON THE MORPHOLOGY OF SPERMATOZOA IN FRESH AND STORED SEMEN

Hours of heating	Average percent of abnormal spermatozoa											
	Tailless heads				True abnormals				Total			
	Fresh semen		Stored semen		Fresh semen		Stored semen		Fresh semen		Stored semen	
	Pulling	Drop	Pulling	Drop	Pulling	Drop	Pulling	Drop	Pulling	Drop	Pulling	Drop
0	10.25	23.00	9.25	9.25	16.75	27.25	24.00	23.50	25.00	48.75	33.00	32.00
2	11.00	16.50	5.75	17.25	19.00	29.75	20.50	26.75	29.25	44.50	26.00	39.75
4	4.75	20.50	3.50	14.25	11.50	30.50	17.75	28.25	15.75	49.00	21.00	41.75
8	5.00	26.50	7.75	5.25	18.25	35.00	13.50	27.50	23.00	59.25	21.00	31.25
16	4.50	35.75	7.00	13.25	15.75	28.25	18.50	32.75	19.75	62.00	24.75	44.50
32	12.50	27.50	4.25	16.25	10.50	27.50	15.75	25.25	22.50	53.00	20.00	40.50
M.M.[1]	8.00	24.96	6.25	12.58	15.29	29.71	18.33	27.29	22.54	52.75	24.29	38.29
S.M.[1]	16.48		9.42		22.50		22.81		37.64		31.29	
G.M.[1]	12.95±8.22				22.66±6.97				34.47±12.37			

[1] M.M. = mean for each method; S.M. = mean for each kind of semen; G.M. = general mean for each of the three spermatozoa classifications.

stored semen and the difference was highly significant. These results suggest that the dead spermatozoa were more elastic and more resistant to physical treatment than live ones. Moench (1929) found that greater force was required on microneedles to pull body pieces from the heads of dead than from the heads of live human spermatozoa. Death was reported to increase the toughness and elasticity of human sperm cells. The percentage of morphologically abnormal spermatozoa was approximately the same in smears made with either fresh or stored semen.

Experiment 2, Clearing of Smears

The second experiment was carried out to compare the two methods with smears of uniform thickness made thin purposely so that half of them might

be stained uncleared. By this means, a comparison of the effect of the clearing process on the proportion of tailless heads and abnormally-formed spermatozoa in smears made with fresh and stored semen was possible.

Forty smears (20 made by each method, 10 to be stained cleared and 10 uncleared) were made with part of a fresh, mixed semen sample composed of two ejaculates. After 8 days of storage at 5° C. the remaining portion of the semen sample was used to replicate these 40 smears. Smears to be cleared

TABLE 2. EFFECT OF METHODS OF MAKING AND CLEARING SMEARS ON THE MORPHOLOGY OF FRESH AND STORED SPERMATOZOA

Smears made with	Percent of abnormal spermatozoa					
	Tailless heads		True abnormals		Total	
	Pulling	Drop	Pulling	Drop	Pulling	Drop
Fresh semen						
Cleared	11.6	15.8	18.5	16.7	28.3	32.1
Uncleared	3.7	9.1	14.0	13.7	16.7	22.2
Average	7.65	12.45	16.25	15.20	22.50	27.15
Stored semen						
Cleared	8.0	3.4	15.3	16.0	22.8	19.1
Uncleared	3.6	4.1	12.6	13.4	15.7	16.8
Average	5.80	3.75	13.95	14.70	19.25	17.95
M. M.[1]	6.72	8.12	15.10	14.95	20.87	22.55
C. M.[1]	9.70		16.62		25.57	
U. M.[1]	5.12		13.42		17.85	
G. M.[1]	7.42±4.08		15.02±3.78		21.71±4.73	

[1] M. M. = individual mean for each method; C. M. = mean for cleared smears; U. M. = mean for uncleared smears; G. M. = general mean for each of the three spermatozoa classifications.

were cleared simultaneously. Then, both the cleared and uncleared smears were stained together.

The averages for the percent of abnormal spermatozoa for each group of ten smears are given in table 2. More tailless heads and abnormally-formed sperm were found in cleared than in uncleared smears made with both the fresh and the stored semen. The differences were highly significant statistically. Also, the proportion of tailless heads was significantly greater in smears made with fresh than with stored semen.

These results suggest several important points. First, a large proportion

of the tailless heads in normal semen may be produced during the clearing process. Second, fresh spermatozoa are more fragile than stored ones. These two findings are additional evidence that such tailless heads are probably artifacts. Third, there is evidence in this experiment that more morphologically normal spermatozoa than abnormal spermatozoa were removed from semen smears during the clearing with chlorazene, because the proportion of true abnormals remaining on the slides was significantly higher on the cleared than on the uncleared slides. Morphologically abnormal spermatozoa apparently have a greater adhesive surface than do normal spermatozoa perhaps due to chemical changes in those abnormals in a stage of decomposition. Thus, the clearing process is believed to be responsible not only for producing a portion of the tailless heads, but for increasing the proportion of true abnormals observed.

The insignificant difference between the two methods of making smears in respect to tailless heads was in agreement with an experiment conducted by Mercier (1946) in which the smears made by the two methods were uniformally thick. The difference in proportion of morphologically abnormal spermatozoa between the two methods of making smears found in the first experiment was not observed in the second experiment. It appears, therefore, that this difference was a result of the thicker layer of semen on the slides prepared by the drop method.

While no statistical difference was found between the means for the two methods of making smears a significant method x semen interaction was observed, namely, more tailless heads were produced by the drop method with fresh semen whether cleared or uncleared.

Experiment 3, Shaking of Semen and Staining of Uncleared Smears

On the basis of the above results a third experiment was conducted to determine if the shaking of semen which occurred in routine handling before shipment to artificial insemination units had an influence on the proportion of tailless heads. In the experiment the routine amount of shaking was compared with approximately double this amount. All smears were made by the drop method and purposely thin so that they could be stained uncleared. Thirty fresh ejaculates of semen from 12 fertile bulls were used. The results are given in table 3.

These data indicate that moderate handling was not an important cause of tailless heads. Furthermore, when the major cause of the tailless heads was known, namely, the clearing process, and that particular step in the staining procedure was eliminated, plus careful handling at every other step, stained semen smears were made in which the presence of tailless heads was almost eliminated.

While not shown in the table an analysis of variance of the data showed that there were no significant differences between bulls in the proportion of tailless heads produced by the method of making these stained smears. These results show that when the above-mentioned precautions were taken the semen of all bulls studied reacted similarly to the techniques employed. This is the first time in our series of investigations that no significant differences were found between fertile bulls in the proportion of tailless heads contained in their semen.

TABLE 3. THE EFFECT OF SHAKING SEMEN ON THE MORPHOLOGY OF SPERMATOZOA (UNCLEARED SMEARS)

Shaking	Percent of abnormal spermatozoa		
	Tailless heads	True abnormals	Total
Routine	1.20	6.13	7.07
2×routine	1.13	6.47	7.30
Mean	1.1167±1.1155	6.25±1.29	7.2±1.55

This fact suggests that the preparation of thin smears to be stained uncleared with aniline gentian violet for one minute, rinsed, dried, and counterstained for 0.5 minute with Ziehl's carbol fuchsin eliminates the proportion of tailless heads which may be considered as artifacts.

Summary and Conclusions

In three experiments conducted to determine the effects of the methods used in making, fixing, and clearing smears and the effect of shaking semen on the proportion of tailless heads and on the proportion of abnormally-formed spermatozoa in smears made with fresh and stored semen of fertile bulls it was found that:

1. The "pulling" and "drop" methods of making semen smears gave the same results when the smears were of uniform thickness.

2. Fixing of smears by heat or by albumin did not influence the proportion of tailless heads or true abnormals.

3. Clearing of smears with 1.0 percent chlorazene was responsible for producing most of the tailless heads and increased the proportion of true abnormals. Normally-formed tailless heads may be artifacts and, consequently, should be included among the true abnormals only when the staining procedures do not produce them.

4. Spermatozoa in fresh semen were much more fragile and more subject to breakage during the clearing process than stored spermatozoa.

5. With the semen of fertile bulls the staining of thin, uncleared smears eliminated most of the tailless heads. This method of preparation of smears for staining should eliminate the tailless heads which are artifacts, and should enable the investigator to distinguish those tailless heads which are truly abnormal.

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REFINING METHODS FOR USING OPAL BLUE STAIN IN EVALUATING RAM SEMEN[1]

L. O. EMIK AND G. M. SIDWELL[2]
United States Department of Agriculture[3]

Introduction

FERTILITY of the sire is a fundamental necessity in maintaining inbred lines. Valuable time is lost both in progress in a line and chronologically if a sterile sire is used. The commercial livestock breeder is not so dependent upon the performance of a single sire because he usually runs several rams with a band, but a fertile sire is of great importance to the breeder of pure-bred livestock who uses one sire to a group of ewes. High fertility is also essential if artificial insemination is to be carried on successfully.

Studies on measurement of the reproductive capacity of rams have been carried on at the Western Sheep Breeding Laboratory for ten years. Terrill (1937) established the basic methods which have been used at this Laboratory as measures of reproductive capacity. Trys at copulation, score estimate of libido, number of ejaculates in 30 minutes for each ram, volume, appearance, viscosity, pH, activity or motility score, percent motile, and concentration of sperm were recorded for each ejaculate and a semen smear was made which was later stained and examined for abnormal sperm. Sperm morphology studies were based upon the method of McKenzie and Phillips (1934). An index of reproductive capacity (normal sperm per 30 minute trial) was based upon the work of McKenzie and Berliner (1937). Reproductive capacity according to Terrill (1937), "seemed in general to be associated with more ejaculations in a given period, larger volumes of semen, higher concentration of spermatozoa, better motility, longer duration of viability and higher proportion of normal spermatozoa."

Lasley, Easley and McKenzie (1942) reported a method of staining with opal blue to differentiate live and dead sperm which was modified by Lasley and Bogart (1943).

The object of this study was to test the value of opal blue as a differential stain for ram sperm. Improvements in the opal blue smear technique and the development of new methods for increasing its usefulness were sought. The feasibility of estimating concentration, percent-live sperm and percent abnormal sperm in one operation with the hemocytometer, by incorporating opal blue into the diluter fluid, was tested.

[1] This work was done in 1942 just previous to the entries of the authors into the armed services.
[2] The assistance and advice of Dr. C. E. Terrill in the problem are gratefully acknowledged.
[3] Western Sheep Breeding Laboratory, Dubois, Idaho.

Materials and Methods

Four Rambouillet rams were used in the experiment, two with exceptionally good semen, 142RW and 2260W, and two with very poor semen, 88RW and 384RW, as determined by pre-breeding tests. Ten cull ewes used for pre-breeding semen tests were retained for this work.

Semen was collected for a trial period of 30 minutes from each ram once a week using ewes out of heat (Terrill, 1937). Rams 142RW and 88RW were used in the morning and 2260W and 384RW in the afternoon. In addition to special tests, the standard tests in use were also made (Terrill, 1937). The pH taken by Hydrion paper was checked with a potentiometer and four concentration counts, two by each worker, were made instead of the usual one. The pH-controlled hematoxylin, carbolfuchsin stained smears were compared with the opal blue stained smears.

Results and Discussion

Determination of optimum concentration of opal blue, optimum pH, and use of eosin in staining semen smears

Opal blue smears were made using 25 percent opal blue Breslau and 1 percent eosin in buffers with the pH values 5.0, 6.7, 7.15, 7.7, and 9.0. The smears of pH 5.0 and 9.0 showed significantly more stained sperm and inferior staining qualities. The pH 7.15 preparation, while not significantly different in numbers of unstained sperm, exhibited a slightly better appearance and more unstained sperm than the pH 6.7 and 7.7 preparations. It was accordingly selected for subsequent work.

Smears were then made using dilutions of opan blue of 0.5, 1.25, 2.5, 12.5 and 25.0 percent in pH 7.15 buffer with eosin proportional to the opal blue 1:25. The 12.5 percent dilution gave uniformly better results. Poor semen samples, especially those containing many leucocytes, may require a higher percent of opal blue due to their decolorizing action.

The time of staining, after mixing semen and stain, was varied from immediate smearing to a delay of four minutes before smearing, using 12.5 percent opal blue and 0.5 percent eosin in pH 7.15 buffer. About 30 seconds was found to be the optimum time in which to obtain good staining without increasing the number of stained sperm. The slides were then dried quickly by placing them on a warming plate over which a draft of air was blown. The slides were examined under the high-dry objective and stored dry. The use of balsam tends to destroy the color contrast between the stained and unstained sperm.

Wet preparations were made under coverslips to see how the sperm reacted upon contact with the stain. A small drop of semen was placed close to a small drop of stain on a slide and the two drops adjoined by applying a coverslip. Motile sperm did not take any stain. Tailless heads, in poor

semen samples, all took eosin but few took opal blue. After motile sperm completely lost their activity, their heads would begin to stain, first at the base, with eosin then opal blue, finally leaving the anterior and posterior halves stained in different intensities of blue and eosin. The ability of normal intact cell membranes to resist the passage of eosin has been well established. In making smears, some live sperm (*sensu strictu*) will be stained due to accidental injury, and some will stain due to chemical injury before the smear can be dried and the staining reaction stopped. It would therefore be reasonable to consider all unstained sperm as live sperm, and their proportion as the best available estimate of the percent of live sperm in the particular sample, under normal conditions of operation.

Eosin was found to be a necessary component, principally due to the inability of tailless heads to stain with opal blue. Eosin alone makes a slide which is relatively difficult to examine. Counts of types of abnormals were compared from opal blue smears, haemocytometer chamber, and pH haematoxylin-carbol-fuchsin stained smears. In addition, types of abnormals were observed in the coverslip preparations. The opal blue smears agreed closely with the haemocytometer preparations and both had the same types of abnormals noted in the coverslip preparations. The pH haemotoxylin-carbol-fuchsin stained smears exhibited abnormalities not present in any of the others, probably due to injury during smearing. Since the opal blue stained smears were superior in a number of respects and inferior in none, this smear technique was adopted as the standard.

Use of opal blue in haemocytometer diluter fluids

Opal blue and eosin were used in various concentrations with various buffers and/or chlorazene as haemocytometer diluter fluids. Glycerin, formalin or phenol were incorporated in certain of the above mixtures. None, of more than 20 combinations, met all the specifications necessary to estimate concentration, percent live sperm and percent abnormal sperm in one operation. The reactions of poor semen indicated that the establishment of a satisfactory opal blue diluter was improbable. It is believed that this was due to the presence of some factor in the semen which caused leucocytes and sperm to clump together. No chemical was found which would resolve this clumping and yet not alter the staining properties beyond usefulness.

The technique was finally abandoned and it was concluded that (1) live and dead sperm could be differentially stained in solution and the percentages reasonably accurately maintained up to 30 minutes after stain and sperm were mixed; (2) clumping could be prevented or resolved reasonably well, giving accurate concentration; (3) the various abnormals present could be identified. More than two of these three abilities could not be successfully combined.

TABLE 1. RELATIONS OF PERCENT LIVE OR LIVE NORMAL SPERMATOZOA (FROM SMEAR) TO MOTILITY SCORES: RELATION A = PERCENT LIVE TO PERCENT MOTILE; RELATION B = PERCENT LIVE NORMAL TO PERCENT MOTILE; RELATION C = PERCENT LIVE TO ESTIMATED MOTILITY COMBINATION; RELATION D = PERCENT LIVE NORMAL TO ESTIMATED MOTILITY COMBINATION

Source of variation		Degrees of freedom	Sums of squares and products			Errors of estimate		r	b	s_b	t	P
			Sx^2	Sxy	Sy^2	Mean square	Degrees of freedom					
142RW	A	15	5375.00	1825.00	3746.50	223.4	14	.407	.340	.204	1.66	—
	B	15	5375.00	1926.25	3643.90	211.0	14	.435	.358	.198	1.81	—
	C	15	5415.00	2077.00	3746.50	210.7	14	.461	.384	.197	1.94	—
	D	15	5415.00	2199.25	3643.90	196.5	14	.495	.406	.191	2.12	—
88RW	A	17	3202.00	2472.89	4468.57	159.9	16	.654	.772	.224	3.45	**[1]
	B	17	3202.00	2298.00	4070.13	151.3	16	.637	.718	.218	3.29	**
	C	17	2500.20	1459.52	4468.57	226.0	16	.437	.584	.301	1.94	—
	D	17	2500.20	2305.80	4070.13	121.5	16	.723	.922	.221	4.18	**
226oW	A	15	15400.94	7856.94	6727.94	194.3	14	.772	.510	.112	4.55	**
	B	15	15400.94	7862.72	6825.99	200.9	14	.767	.511	.114	4.48	**
	C	15	16202.44	8385.79	6727.94	170.5	14	.803	.518	.103	5.02	**
	D	15	16202.44	8384.95	6825.99	177.6	14	.797	.518	.105	4.93	**
384RW	A	17	3144.28	1186.20	1460.24	63.3	16	.554	.377	.142	2.66	*
	B	17	3144.28	945.92	888.13	37.7	16	.566	.301	.110	2.73	*
	C	17	1771.59	775.28	1460.24	70.1	16	.482	.438	.199	2.20	*
	D	17	1771.59	640.89	888.13	41.0	16	.511	.362	.152	2.37	*
Sum of	A	64	27122.22	13341.03	16403.25	156.2	63	—	.492	.076	6.46	**
	B	64	27122.22	13032.89	15428.15	145.5	63	—	.481	.073	6.58	**
	C	64	25889.23	12697.59	16403.25	161.5	63	—	.491	.079	6.20	**
	D	64	25889.23	13530.89	15428.15	132.6	63	—	.523	.072	7.25	**

[1] * = Probability less than 5 percent; ** = Probability less than 1 percent.

Accuracy of motility estimates

Motility score and percent of motile sperm were tested by regression methods for reliability in estimating the percentages of live and normal sperm, as determined by counts from opal blue stained smears. Four relations were tested; *i.e.* A. estimated percent motile versus percent live spermatozoa; B. estimated percent motile versus percent live normal; C. estimated motility combination (EMC) versus percent live; D. estimated motility combination versus percent live normal, where estimated motility combination was percent motility times motility score when motility scores were converted as follows: 1 = 1.0, 2 = 0.9, 3 = 0.8, 4 = 0.7, 5 = 0.6, 6 = 0.0. The analyses are given in table 1. The four relations, A, B, C, and D, do not vary significantly between one another as judged by their regression coefficients, nor does any one of them vary significantly between rams. All four regression coefficients are highly significant, *i.e.* ability to predict Y from X, for the sum of all rams, but probability is near the 2 percent level

for 384RW and just above the 5 percent level for 142RW, when the rams are considered individually. The relation, D, shows slightly better results in general. Further refinements of the relationship will be investigated in a more extensive study to be made soon.

Opal blue stained smears have been made on all ejaculates during subsequent annual testing of rams. This technique has proved more rapid and simpler than previous ones. It has the decided advantage of producing a stained smear during examination of the semen sample, thus allowing immediate observation of abnormalities in morphology of the spermatozoa. The quality of these smears did not depreciate noticeably in a period of four years of storage in boxes. The same stain solution which was made in 1942 has been used during subsequent years, and was still in perfect condition upon recent testing when four years old. The solution was heated and filtered once each year before use. It has not been protected against light.

Summary

For ram's semen the optimum stain mixture for opal blue Breslau and eosin was found to be: 12.5 percent opal blue and 0.5 percent eosin in pH 7.15 phosphate buffer. It was necessary to stain for 30 seconds before smearing. The dry smears were most suitable for observation. Balsam or oil decreases the color contrast. No suitable method was found to incorporate opal blue and eosin into a diluting fluid for use in the haemocytometer.

Under normal conditions of examination motile sperm took no stain, and unstained sperm were therefore regarded as the best estimate of the live sperm.

Prediction of percent live normal spermatozoa (on smear) from a combination (EMC) of the motility score and estimated percent motile had significant reliability.

The opal blue staining method was found to be simpler and more rapid than previous methods, allowing immediate examination for abnormalities of the sperm during routine examination of semen. The slides and the stain solution exhibited no noticeable depreciation after four years.

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WOOL FIBER DENSITY OF SHROPSHIRE LAMBS

JOHN I. HARDY AND HAROLD W. WOLF
United States Department of Agriculture[1]

THE wool density of Shropshire weanling lambs was compared with that of the same lambs as yearlings in this investigation. The question to be answered was, do the lambs which have the densest fleeces as weanlings maintain their leadership in density as yearlings? In a similar investigation on range sheep, Lambert, Hardy, and Schott (1938) made a survey of the relation between the fleece characteristics of weanlings and yearlings and found that the results, for the most part, indicated a useful predictive value for length of wool and percent of clean wool, but not for density and fineness of fiber. Pohle (1942) enlarged on the preliminary study by Lambert and coworkers. His low correlations between the density index, centigrams of clean dry wool per cubic centimeter of staple, at 20 and 52 weeks may have been the result of the difficulties in the measurement of the sheared area of skin and the staple length upon which the density index was calculated. The earlier methods for determining density required the counting of all the fibers in an aliquot part of the entire sample. Because of the slowness of this method, Pohle (1942) and Lambert, Hardy, and Schott (1938) used the weight of clean wool per unit volume as a density index. In this investigation a more efficient cross-section-area method was used, which made it possible to measure a large number of density samples in a short time. This method is described by Hardy and Wolf (1942).

Ten Shropshire lambs were used in this experiment from the purebred flock of the Bureau of Animal Industry maintained at the Agricultural Research Center, Beltsville, Maryland. Samples from seven body regions were taken with the Hardy density clippers, Hardy (1942) in the summer of 1940 when the lambs were 20 weeks of age (around weaning time) and again in the spring of 1941 when they had attained the age of 52 weeks.[2] The variations in fiber density at these two periods and their relationship to wool production were determined.

Apparatus and Materials

The 10 Shropshire lambs were selected on the basis of being thrifty, healthy individuals and having body weights close to the average for Shropshire lambs.

The samples were taken with a clamping type of wool density calipers

[1] Agricultural Research Center, Beltsville, Maryland.

[2] For the body weights and measurements, the authors are indebted to R. G Schott and V. L. Simmons of the Bureau of Animal Industry. For many fiber measurements, the authors acknowledge the assistance of E. B. Bertone formerly with B.A.I., now at Colorado State College, Fort Collins, Colorado.

similar in design to the Wira instrument (Wolf *et al.*, 1943). The adjustment of the calipers was such that a lock of wool was removed from one square centimeter of skin area. Samples were taken from the left side of the fleece at 20 weeks of age and on the right side at 52 weeks. At the two periods, samples were also taken from each sheep from the following seven body regions: (1) At the neck, over point of shoulder, (2) On the back, directly above the middle of the side, (3) On the back, just anterior to dock, (4) At the shoulder, on the point of the shoulder joint of the scapula and humerus bones, (5) Middle of side below region 2, (6) Over joint of hip, (7) On the belly below region 5. From each region, five duplicate samples were removed with the calipers from within a skin area of 16 square inches.

The fiber density, the number of fibers per square centimeter of skin area, was estimated by the procedure reported by Hardy and Wolf (1942). These measurements were made on the clean sample at a location one-fourth of an inch from the base end of each bundle of fibers. The over-all length of fibers in the straightened staple was measured to the nearest millimeter.

The fineness of wool expressed in terms of the fiber diameter in microns was determined by the count method (Hardy and Wolf, 1939).

The weight of each animal in pounds was taken at 20 and 52 weeks of age. Length of body from scapula to pin bone, depth of chest, and width of chest were taken in centimeters at both ages by means of sliding-bar calipers.

The sheep were sheared as yearlings (52 weeks), the fleeces were scoured with soap and water, and the moisture-free clean wool was weighed.

Formulas for Calculating Fiber Density

The following formulas have been developed to estimate the fiber density from the total yield of clean wool and various body measurements.

By the use of a formula similar to that given by Bosman (1934), the number of fibers per gram of clean wool may be calculated. The average diameter and average length being known, the number of fibers per gram of wool is calculated as follows:

$$N = \frac{4(10^8)}{1.3\ (D^2\ L)} \qquad (1)$$

where N = number of fibers per gram of clean wool, D = mean diameter in microns, L = mean length in centimeters, $= 3.1415$, and 1.3 = density of wool fiber.

The total number of wool fibers in the fleece, therefore, may be estimated by multiplying formula (1) by weight of clean wool as follows:

$$N_T = \frac{4(10^8)W}{1.3\ (D^2\ L)} \qquad (2)$$

where N_T = total number of wool fibers, and W = clean weight of the fleece.

There are a number of methods (Brody and Campbell, 1938) available to estimate the surface area of a sheep. Unpublished data on volume of Shropshire lambs at yearling age were obtained by Phillips (1937) and could be applied directly to these sheep. He has shown that for each pound of body weight, a yearling Shropshire lamb occupies 453.95 cubic centimeters of volume. Assuming that the volume of the body and the surface area could be calculated and that a sheep is of parallelepiped shape, ordinary formulas are then applicable:

$$V = LS^2 \tag{3}$$

where, V = volume in cubic centimeters, L = length from scapula to pin bone in centimeters (*i.e.*, length of parallelepiped), S = average of depth and width of chest in centimeters (*i.e.*, height and width of the parallelepiped) and:

$$A = 4LS + 2S^2 \tag{4}$$

where A = surface area in square centimeters.

To convert the volume to area so as to make use of the Beltsville data, volume must be multiplied by the quantity, $(4/S)+(2/L)$, to obtain the value for the surface area per pound of body weight, formula 4.

The total volume of a sheep is determined by the formula:

$$V = 453.95\ W_B \tag{5}$$

where W_B = body weight in pounds.

The total surface area can then be calculated from equation (5) by multiplying by $(4/S)+(2/L)$,

$$A = 453.95\ W_B\left(\frac{4}{S}+\frac{2}{L}\right) \tag{6}$$

where A = total surface area in square centimeters.

It is believed that this surface area is more satisfactory than the areas calculated from the logarithmic function of weight which has been employed in metabolism studies. The surface area available for wool production is necessarily less than the total skin area due to some normal wool-free areas. Added precision results from the consideration of both body measurements and weight in formula (6) (Hardy and Wolf, 1939).

Predicting Yearling Clean Wool Content of Fleeces from Measurements Made at 20 Weeks

It has been shown that the number of fibers in a fleece may be calculated from the fiber diameter, length of staple and total weight of clean wool. Moreover, if the surface area of sheep is known, the fiber density can be estimated. Conversely, it is possible to estimate the clean weight of wool at any time if the skin area, fiber density, diameter of fiber and length of staple are known. The skin area producing wool fiber may be calculated from

formula (6) developed earlier. The weight of one fiber is calculated from the reciprocal of formula (1) and is as follows:

$$\text{Weight of one wool fiber} = \frac{1.3(D^2 L)10^8}{4}. \quad (7)$$

The total clean wool content of the fleece now may be predicted at any time providing the fiber density is known, using the following relationship:

$$\text{Clean wool content} = \text{fiber density} \times \text{surface area} \times \text{weight of one wool fiber} \quad (8)$$

Therefore, the clean wool content at any early stage of development, 20 weeks in this case, may be used to predict the clean wool content at 52 weeks.

Results and Discussion

Fiber Density

The mean fiber density of the 10 lambs was found to vary from 1917 to 3035 fibers per square centimeter at 20 weeks of age and from 1438 to 2304 fibers per square centimeter at 52 weeks (see table 1). The average fiber density was 2517 fibers per square centimeter at 20 weeks and 1970 at 52 weeks of age, a decrease in fiber density of over 20 percent during this period of growth. Variations also occurred between the seven body positions sampled for density at the two periods. At 20 weeks, the positions ranked for density as follows: neck—3146, shoulder—3014, dock—2997, hip—2446, back—2382, side—2062, and belly—1582. The order of density at 52

TABLE 1. FIBER DENSITY OF SHROPSHIRE LAMBS AT 20 AND 52 WEEKS OF AGE. DENSITIES ARE GIVEN AS NUMBERS PER SQUARE CENTIMETER

Sheep numbers	Region and age															
	Region 1 Neck		Region 2 Middle of back		Region 3 Anterior to dock		Region 4 Shoulder		Region 5 Side		Region 6 Hip		Region 7 Belly		Mean	
	20	52	20	52	20	52	20	52	20	52	20	52	20	52	20	52
1	2933	2545	2202	1662	3121	2142	3846	2484	2190	1637	2969	2304	2905	1076	2880	1961
2	3356	2388	2216	1787	3372	2099	3544	2533	2939	1747	3525	2091	1399	1269	2899	1987
3	3408	2729	2554	2005	3552	2499	3393	2895	2842	2118	3063	2062	2437	1826	3035	2304
4	2642	2055	2041	1148	3017	1693	2176	2851	1391	1885	1852	1857	1325	1203	2063	1813
5	3605	3032	2913	1583	2858	2237	2878	2554	2207	2081	2522	1996	1209	1768	2598	2178
6	2992	2739	2336	1923	2646	2423	3034	2947	1670	1495	2062	2263	1362	1108	2300	2128
7	3148	2400	2880	1685	3319	1787	3482	2915	1801	1768	2165	2039	1580	1580	2625	2028
8	2392	1915	1734	1334	2318	1476	2135	2521	1901	1555	1790	1658	1145	910	1917	1624
9	3659	2908	2773	1871	3417	2025	3434	3278	1821	2332	1993	1953	1330	1314	2632	2240
10	3329	1871	2161	1162	2347	1499	2219	2184	1863	1264	2534	1298	1134	791	2224	1438
Mean	3146	2458	2382	1616	2997	1988	3014	2716	2062	1788	2446	1954	1582	1284	2517	1970

weeks was shoulder, neck, dock, hip, side, back, and belly, being essentially the same as at the earlier period.

It was possible to show by means of analysis of variance, table 2, that highly significant differences existed between sheep, between regions, and between ages. Within the body region, the lock differences are significant. Since the location of the locks within the region has been fixed and locks were not taken at random as in the earlier Rambouillet study (Wolf *et al.*,

TABLE 2. ANALYSIS OF VARIANCE OF THE FIBER DENSITY OF TEN SHROPSHIRE LAMBS AT 52 WEEKS OF AGE (FIBERS PER SQUARE CENTIMETER)

Source of variation	Degrees of freedom	Sum of squares	Mean square	Value of *F*
Sheep	9	56,689,480	6,298,831	22.48**
Region	6	157,966,179	26,327,696	93.95**
Age	1	52,292,130	52,292,130	186.60**
Lock	4	2,864,110	716,028	2.56*
Sheep-region	54	24,040,138	445,188	1.59*
Sheep-age	9	12,114,400	1,346,044	4.80**
Sheep-lock	36	11,182,402	310,622	1.11
Region-age	6	12,056,531	2,009,418	7.17**
Region-lock	24	6,162,598	256,775	1.09
Age-lock	4	9,177,330	2,294,333	8.19**
Sheep-region-age	54	27,080,162	501,484	1.79**
Sheep-region-lock	216	61,375,220	284,145	1.01
Sheep-age-lock	36	7,969,658	221,379	1.27
Region-age-lock	24	2,989,574	124,566	2.25*
Remainder	216	60,530,361	280,233	
TOTAL	699	504,490,273		

* Significant.
** Highly Significant.

1943), the differences may have been due to the order of sampling or to differences in the density pattern. The highly significant values shown by the interaction, ages times locks, indicates that the pattern probably did change between 20 and 52 weeks.

The differences in the pattern of fiber distribution over skin areas may be partially due to the more concentrated sampling of the region at 52 weeks compared to a greater density of fibers at 20 weeks. In other words, the number of available wool-producing follicles is perhaps constant at both pe-

riods, but as the animal grows, these follicles are distributed over a larger area.

Areas of the same size were sampled at both ages so the fiber pattern at 52 weeks can be likened to a magnified portion of the pattern at 20 weeks. However, at 20 weeks, the order of sampling had the effect of reducing the size of lock as the sampling progressed (see table 3). Fiber density of the locks in the front-back sector was significantly greater than that of the locks in the rear-belly portion, based on the number of fibers required to show significant differences given in table 3. A gradient existed across the small body area from which the five samples were removed.

TABLE 3. AVERAGE FIBER DENSITY WITHIN THE REGIONS

Lock number	Sampling order	Position within region	Fiber No. per Sq. Cm.	
			at 20 wks.	at 52 wks.
1	2	Front-back sector	2718	2073
2	3	Rear-back sector	2559	1867
3	4	Front-belly sector	2412	2065
4	5	Rear-belly sector	2327	1880
5	1	Middle of region	2578	1975

TABLE 4. NUMBER OF WOOL FIBERS REQUIRED TO SHOW SIGNIFICANT DIFFERENCES

Comparisons made	Number of fibers	
	5% level	1% level
Between sheep	257	345
Between regions	213	283
Between ages	79	104
Between locks	178	237

The utilization of measurements made at 20 weeks to predict the density at 52 weeks appeared practical. Assuming that the best estimate of the error was the remainder in table 2, the standard deviation became ± 529 fibers. The numbers of fibers required to show significant differences between sheep at 5 percent and 1 percent levels are given in table 4. With 257 fibers as the necessary difference, sheep numbers 8 and 10 differ significantly from numbers, 1, 2, 3, 5, 7, and 9 at both 20 and 52 weeks of age. The differences which are highly significant at 52 weeks in general have been shown to be so at 20 weeks. For example, out of 17 highly significant differences in 45 possible combinations compared at 52 weeks, 15 of these same combinations are highly significant at 20 weeks. The mean fiber densities at 20 weeks

of each individual based on the seven body regions are highly correlated with density at 52 weeks.

It would be desirable, however, to reduce the total number of locks sampled by limiting the regions sampled. Individual body regions at 20 weeks are unfortunately not significantly correlated with the same regions at 52 weeks with the exception of the neck regions. The dock, back and shoulder at 20 weeks are all significantly correlated with the average of the seven regions at 52 weeks. At both periods, the dock, side, and hip are significantly correlated with the average remaining positions. From above considerations, the dock appeared to be the best region to sample if only one is to be sampled. A separate analysis of variance made on the seven regions shows that all regions differentiate between sheep.

TABLE 5. ESTIMATED FIBER DENSITY AT 52 WEEKS OF AGE, AND WEIGHT OF CLEAN WOOL

Sheep number	Total number of fibers covering the body[1]	Total wool producing area square Cm.[2]	Estimated fiber density, No. per Sq. Cm.
1	19,045,749	8616	2210
2	21,929,514	10,314	2126
3	22,017,840	7404	2974
4	16,509,535	8339	1980
5	17,576,295	7967	2206
6	19,401,684	8625	2249
7	19,993,096	8861	2256
8	17,267,013	9742	1772
9	18,017,825	7209	2499
10	16,732,770	8280	2021
Average	18,849,132	8536	2208

[1] Determined by applying formula 2.
[2] Determined by applying formula 6.

It has been shown herein that the fiber density decreased considerably with the growth of the lambs from 20 to 52 weeks of age. Apparently, there was intimate connection between fiber density and growth of the lamb. If the amount of clean wool and size of the lamb are known, it should be possible to calculate the density of wool fiber. Formulas 2 and 6 were used to calculate the wool fiber density at 52 weeks of age. The estimated fiber density, table 5, is highly correlated with the actual density, $r = 0.78$. This means that the sheep are ranked approximately in the same order by either the estimated or actual value. Sheep number 3, which had the highest fiber density, had an estimated total of over 22 million wool fibers. Roughly, the total fiber population of a Shropshire lamb may be estimated by multiplying the fiber density at 52 weeks of age by 10,000.

The total fiber population covering the body of the 10 lambs at 52 weeks of age is given in table 5. The average number of fibers is 18,849,132.

Predicting Clean Wool Content

From formulas developed, the clean wool content of the fleeces has been calculated at 20 and 52 weeks from fiber and body measurements. These estimations are given in table 6 and are compared with the scoured wool

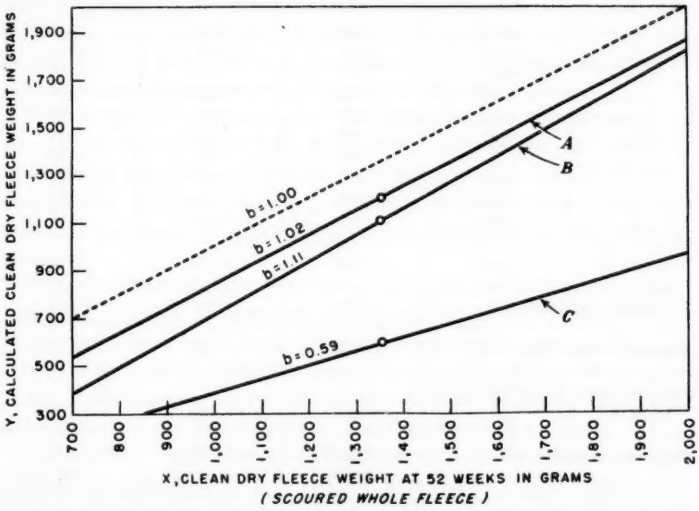

Figure 1. Regression relationship of clean fleece weights calculated from fiber and body measurements on clean fleece weight at 52 weeks in which regression "A" is from fiber and body measurements made at 52 weeks; "B" from fiber and body measurements made at 20 weeks, with compensation for wool growth; "C" from fiber and body measurements made at 20 weeks.

weight at 52 weeks. The estimated clean wool weights ranked the sheep in approximately the same order as the scoured value did. The last column in table 6 gives the estimated clean wool content at 52 weeks from fiber and body measurements. All estimates are significantly correlated with the scoured fleece weight. A study of the regression of three calculated values on the scoured weight at 52 weeks is given in figure 1. The regression relationship is significant at the 1% level (table 6). The slopes represented by the "b" are for all practical purposes unity. The regression lines in figure 1 may be used to estimate the clean wool content at 52 weeks from fiber and body measurements taken at 20 weeks.

TABLE 6. CLEAN DRY WOOL CONTENT OF FLEECES IN GRAMS

Sheep No.	X 52-weeks weight	Y 20-weeks weight	Y_2 52-weeks weight	Y_3 52-weeks weight
	Determined by scouring whole fleece at 52 wks.	Estimated from 20-wks. measurements	Estimated from 20 wks. measurements corrected for 52 wks. length in staple	Estimated from 52 wks. measurements
1	1515	892	1627	1344
2	1738	820	1567	1624
3	1467	584	1123	1136
4	1353	576	1068	1240
5	1383	577	1115	1366
6	1341	568	1068	1269
7	1532	585	1141	1377
8	1203	377	744	1103
9	964	361	675	864
10	1080	558	1007	768
Mean, X	1358	590	1113	1209
Correlation coefficient, Y		0.785	0.841	0.918
Regression coefficient, by X		0.566	1.108	1.020
Standard error of regression coefficient, S.E.		0.158	0.255	0.155
Regression equation		$Y=0.566X$ -178.602	$Y=1.108X$ -390.721	$Y=1.020X$ -175.652
Regression equation, transposed for estimating		$X=1.767Y$ $+315.551$	$X=0.903Y$ $+352.636$	$X=0.980Y$ $+172.208$

The correlation coefficient between the estimated and scoured value at 52 weeks increased from 0.78 when based entirely on 20 weeks data to 0.84 when compensated for the growth at 52 weeks and finally to 0.94 when based entirely on 52 weeks fiber and body data. The estimation at 52 weeks has been incorporated in table 6 and figure 1 for its theoretical interest as it indicated the close tie-up between production of wool and the factors of skin area, fiber diameter, fiber density and fiber length.

Summary

Wool fiber densities are discussed, results being obtained from 10 Shropshire lambs, sampled at 20 and 52 weeks of age. Seven body regions were considered: neck, back, dock, shoulder, side, hip, and belly. Fiber measure-

ments were made near the base end of each lock by the method proposed by Hardy and Wolf (1942).

The average fiber density at 20 weeks of age was 2517 fibers per square centimeter compared with 1970 fibers per square centimeter at 52 weeks of age. The high and low density regions when the lambs were 20 weeks of age were also high and low regions at the age of 52 weeks. The density at 20 weeks was highly correlated with density at 52 weeks. However, certain individual regions were not significantly correlated at the two periods. The dock, back, and shoulder fiber densities at 20 weeks are significantly correlated with the fiber density at 52 weeks for the same locations. From all considerations, analysis was to be limited to only one region.

From weight of clean wool and body measurements, it was possible to estimate the fiber density of the sheep at 52 weeks of age. The estimated value ranked the sheep in practically the same order as did the measured fiber density. The wool producing area upon which the fiber density was estimated was based on a formula developed from sheep volume measurements.

Differences between sheep, body regions, locks and ages are all highly significant. The differences within the regions may be due to order of sampling or more likely to gradients within the 16 square inch area sampled. The fiber density moreover changed during the growth period from 20 to 52 weeks. Indications were that the number of wool producing follicles remained constant but that they were spread out by the skin growth.

A method for early selection of sheep for wool production has been developed, use being made of fiber density, fiber diameter, fiber length, body weight and body size. The correlations between the estimates and scoured value of clean wool at 52 weeks were highly significant. A significant regression relationship existed between these estimates and clean wool at 52 weeks. This provides a method of estimating from weanling measurements the clean wool content of a fleece at 52 weeks.

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BREED CROSSES USED IN THE DEVELOPMENT OF TARGHEE SHEEP

CLAIR E. TERRILL
United States Department of Agriculture[1]

THE development of the Targhee breed of sheep began in 1926 when the Bureau of Animal Industry at the U. S. Sheep Experiment Station, Dubois, Idaho mated select Rambouillet rams with select ewes of Corriedale × Lincoln-Rambouillet and Lincoln × Rambouillet combinations. Descendants of these crosses have been interbred and carefully selected to produce Targhee sheep.

Spencer and Stoehr (1941) have described the characteristics of Targhees and the reasons for their development. Much of the western range is adapted to the use of range ewes of fine wool foundation but carrying some long wool breeding. These ewes are larger than fine wool ewes and are generally considered more profitable where range conditions are suitable. The Targhee was developed to stabilize this type in a breed approximately one-fourth long wool breeding and three-fourths fine wool breeding. This type is generally recognized as the "comeback" in the West, a name which signifies coming back to the Rambouillet from the first coarse and fine wool cross.

The Targhee is a polled white-faced sheep of intermediate size. The ideal Targhee has a more desirable mutton conformation than five-wool sheep, is free from skin folds, and has an open face. Targhees shear heavy fleeces of long staple wool which generally grade ½ Blood and which are moderately light in shrink. Representative yearling ewes are shown in figures 1 and 2.

After about 3 generations of Targhee breeding (in about 1938) it had become apparent that a very desirable range breed had been developed. It was then thought desirable to increase numbers and broaden the base of the breed so that an adequate breeding program could be conducted.

In the fall of 1938 Rambouillet rams were mated to unregistered Corriedale ewes (which had resulted from several generations of crossing Corriedale rams on Lincoln-Rambouillet ewes) and this cross was repeated for several years. Some registered Corriedale ewes were included. In the following years other crosses were made involving Columbia rams × Rambouillet ewes (K × R), Targhee rams × Rambouillet ewes (T × R), Targhee rams × Corriedale ewes (T × A), Targhee rams × Lincoln-Rambouillet ewes (T × LR) and a Tasmanian Merino-Rambouillet ram × Lincoln Rambouillet and Columbia ewes (TM-R × LR & K).

The object of this study is to summarize the weanling and yearling rec-

[1] U. S. Sheep Experiment Station, Dubois, Idaho.

ords of ewes resulting from the above crosses and to examine their suitability for foundation Targhee sheep

Material and Methods

Data were studied from 1,014 weanling lambs born during the years from 1940 to 1945 and from 701 yearling ewes born from 1938 to 1944. The records used were taken as a routine part of the breeding program of the U. S. Sheep Experiment Station, Dubois, Idaho.

The lambs were born during April and May and were herded with their

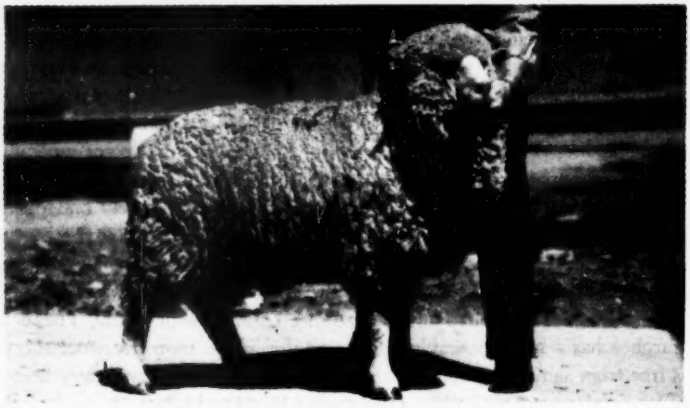

Figure 1. A representative Targhee yearling ewe.

dams on sagebrush-grass or spring-fall range near Dubois, Idaho, until about June 1. They were then herded on the high summer range until about the middle of September when they returned to the fall range. The ewe lambs were separated from their dams at this time and remained on this fall range until December when they were trailed to the winter feed lot and were fed alfalfa hay. They were returned to the spring range around May 1 and yearling records were taken around June 1.

Weanling records were taken during the middle or latter part of August at about 120 days of age. Weaning weights were taken to the nearest pound. Staple length was measured at the middle of the side to the nearest 0.2 cm. by a committee of 2 or 3 experienced animal husbandmen working independently. The same or a similar committee gave scores for mutton type, condition (degree of fatness), face covering and neck folds. In some cases the weanling condition score was taken by one man. The same scoring system was used for each trait. Lambs considered as having highest merit were

given a score of 1 and those with poorest merit a score of 5. Fifteen scoring units were obtained by assigning plus or minus values to lambs having scores slightly above or below the whole unit. The scores given by the two or three judges were averaged and rounded off to the nearest scoring unit of $\frac{1}{3}$. For example, two animals with scores of 3, 3 and 3+ and 3, 3 and 3−, respectively, would each be assigned scores of 3.0 as their final weaning

Figure 2. A group of Targhee yearling ewes at about 13 months of age.

records. Negative differences or smaller numerical values indicate increase in merit with all scores used.

The traits evaluated at weanling age were also measured and scored in the same manner at yearling age. Staple length and face covering were evaluated just prior to shearing which took place about June 1 of each year. Scores for mutton type, condition, and neck folds were taken just after shearing. Fleece weight to the nearest 0.05 pound and body weight to the nearest pound after shearing were taken at the time the sheep were shorn. Clean yields were obtained by scouring small samples taken from the middle of the side. Small samples were not taken on all yearling ewes studied. Clean fleece weights were obtained by multiplying the clean yield (on a commercial basis, i.e., containing 12 percent moisture) by the adjusted grease fleece weights. Commercial fleece grades were taken on the shearing floor by an experienced wool grader for the years from 1942 to 1945 inclusive.

Weanling records were adjusted for differences due to environmental effects for Targhee lambs (Hazel and Terrill, 1946) to a basis of noninbred, single ewe lambs, 120 days of age, from mature dams. Yearling rec ·ds were

adjusted in the same manner to a basis of noninbred, single ewes, 406 days of age, from mature dams, according to the differences for yearling Targhee ewes found by Terrill, Sidwell and Hazel (1946). In addition, corrections were made according to the yearly differences in averages for weanling and yearling Targhee ewes. Significance of mean differences were tested by use of the appropriate variances for Targhee ewes presented by Hazel and Terrill (1946) and Terrill, Sidwell and Hazel (1946).

Results

Means for weanling and yearling traits for the various breed-crosses and Targhees are presented in tables 1 and 2 respectively. Differences between

TABLE 1. MEAN VALUES FOR VARIOUS WEANLING TRAITS OF TARGHEE AND BREED-CROSS EWE LAMBS

Breed of sire	Breed of dam	Symbol for breeds	Number of years studied	Number of sires	Number of weanling ewes	Means[1]					
						Staple length	Weaning weight	Mutton type	Condition	Face covering	Neck folds
						centimeters	*pounds*	*score*	*score*	*score*	*score*
Columbia	Rambouillet	K×R	3	22	251	3.80	79.19	1.96	1.90	3.53	1.34
Rambouillet	Corriedale	R×A	3	4	50	4.14	76.61	1.96	2.16	4.15	1.22
Targhee	Corriedale	T×A	2	8	26	4.73	77.32	1.83	2.15	3.25	1.03
Targhee	Lincoln-Rambouillet	T×LR	1	1	8	4.31	78.97	1.99	1.90	3.64	1.04
Targhee	Rambouillet	T×R	1	4	80	3.45	74.36	2.03	2.23	4.17	1.59
Targhee	Targhee	T	6	52	599	3.91	76.44	1.87	2.01	3.63	1.19

[1] Scores were assigned from 1 to 5 with 1 indicating the highest merit and 5 the poorest merit.

the means of the breed-crosses and Targhees are presented in table 3. Values for clean yield and clean fleece weight are presented in table 4. The proportion of fleeces classified in the various commercial grades are shown in table 5.

With the exception of the T×R cross all the breed crosses were superior to Targhees in grease fleece weight, while K×R, R×A and TM·R×LR& K were significantly greater. Differences in staple length were consistent at weanling and yearling age. T×A ewes had the greatest staple length followed in order by T×LR and R×A all of which had greater staple length at both ages than Targhees. Crosses K×R and T×R had significantly shorter staple than Targhees. In general the crosses with the longer staple had the higher clean yield. Pohle and Keller (1943) found a definite relationship of both clean yield and clean fleece weight to length of staple. All of the crosses except T×R produced heavier clean fleece weights than Targhees.

TABLE 2. MEAN VALUES FOR VARIOUS YEARLING TRAITS OF TARGHEE AND BREED-CROSS EWES

Breed of sire	Breed of dam	Symbol for breeds	Number of years studied	Number of sires	Number of yearling ewes	Means[1]						
						Grease fleece weight	Staple length	Body weight	Mutton type	Condition	Face covering	Neck folds
						pounds	*centimeters*	*pounds*	*score*	*score*	*score*	*score*
Columbia	Rambouillet	K×R	2	6	72	11.02	7.84	94.79	1.74	1.84	3.35	1.71
Rambouillet	Corriedale	R×A	5	7	96	11.19	9.00	94.67	2.11	2.05	3.62	1.48
Targhee	Corriedale	T×A	2	8	21	10.98	9.99	88.54	2.02	1.94	3.18	1.51
Targhee	Lincoln Rambouillet	T×LR	1	1	6	10.75	9.15	88.96	1.92	1.96	3.43	1.57
Targhee	Rambouillet	T×R	1	4	60	10.42	7.04	90.20	1.82	1.79	4.20	1.83
Tasmanian Merino-Rambouillet	Lincoln-Rambouillet and Columbia	TM-R× LR&K	1	1	7	11.45	8.50	95.62	2.31	2.11	3.19	2.33
Targhee	Targhee	T	7	49	439	10.52	8.61	88.19	1.95	1.93	3.49	1.60

[1] Scores were assigned from 1 to 5 with 1 indicating the highest merit and 5 the poorest merit.

TABLE 3. MEAN DIFFERENCES OF BREED-CROSS EWES FROM TARGHEE EWES AT WEANLING AND YEARLING AGE

Breed	Differences for weanling means[1]						Differences for yearling means[1]						
	Staple length	Weight	Mutton type	Condition	Face covering	Neck folds	Grease fleece weight	Staple length	Weight	Mutton type	Condition	Face covering	Neck folds
	centimeters	*pounds*	*score*	*score*	*score*	*score*	*pounds*	*centimeters*	*pounds*	*score*	*score*	*score*	*score*
K×R	−0.11†	+2.75†	+0.09†	−0.11†	−0.10*	+0.15†	+0.50†	−0.77†	+6.60†	−0.21†	−0.09†	−0.14	+0.11†
R×A	+ .23†	+ .17	+ .09	+ .15*	+ .52†	+ .03	+ .67†	+ .39†	+6.48†	+ .16†	+ .12†	+ .13†	− .12†
T×A	+ .82†	+ .88	− .04	+ .14	− .38†	− .16	+ .46	+1.38†	+ .35	+ .07	+ .01	− .31*	− .09
T×LR	+ .40*	+2.53	+ .12	− .11	+ .01	− .15	+ .23	+ .54	+ .77	− .03	+ .03	− .06	− .03
T×R	− .46†	−2.08	+ .16†	+ .22†	+ .54†	+ .40†	− .10	−1.57†	+2.01†	− .13†	− .14†	+ .71†	+ .23†
TM-R×LR&K							+ .93	− .11	+7.43†	+ .36*	+ .18	− .30	+ .73†

* Signifies probability of chance occurence <.05.

† Signifies probability of chance occurrence <.01.

[1] Scores were assigned from 1 to 5 with 1 indicating the highest merit and 5 the poorest merit.

The T×A and T×LR crosses had a higher proportion of fleeces in the coarser grades. Both R×A and K×R crosses were predominately ½ Blood as were the Targhee ewes. Hultz *et al.* (1935) found that Corriedale ×

TABLE 4. MEAN CLEAN YIELDS AND CLEAN FLEECE WEIGHTS FOR BREED-CROSS AND TARGHEE YEARLING EWES

Breeds	No. of head	Commercial clean yield	Clean fleece weight
		percent	*pounds*
K×R	29	47.16	5.17
R×A	89	48.13	5.39
T×A	10	55.24	6.23
T×R	31	44.95	4.68
TM-R×LR & K	7	46.83	5.36
T	303	46.20	4.86

TABLE 5. COMMERCIAL GRADES OF FLEECES FROM BREED-CROSS AND TARGHEE YEARLING EWES

Breeds	No. of head	Percent of fleeces graded in:				
		Fine French	Fine staple	1/2 Blood	3/8 Blood	1/4 Blood
K×R	72	—	15	79	6	—
R×A	12	—	8	92	—	—
T×A	21	—	—	71	24	5
T×LR	6	—	—	33	67	—
T×R	60	2	53	42	3	—
T	285	—	5	80	13	2

Rambouillet crossbreds produced about equal proportions of ½ Blood and ⅜ Blood fleeces. A majority of the T×R fleeces fell in the Fine grades.

The K×R cross had significantly heavier weaning weights than Targhees. None of the other crosses were significantly different from Targhees at weaning age although the T×R lambs were about 2 pounds lighter. The TM-R×LR & K, K×R, R×A and T×R crosses were all significantly heavier than Targhees at yearling age.

The K×R cross had significantly poorer type and better condition at weanling age but both type and condition scores were significantly better than Targhees at yearling age. The T×R cross had significantly poorer type and condition at weanling age but both traits were significantly better than those for Targhees at yearling age. Type and condition scores for the R×A cross were poorer at both ages than Targhees. Except for weanling type the differences were all highly significant. The TM-R×LR & K cross

had the poorest type of any of the crosses at yearling age. None of the other differences for type and condition at either age were large or significant.

Consistent differences in face covering among breed crosses were found at both weanling and yearling age. T×A cross were the most open faced followed by TM-R×LR & K, K×R, and T×LR. The last group were practically identical in face covering to Targhees. R×A and T×R ewes had significantly more wool covering on the faces than Targhees at weanling age. At yearling age the difference was even greater for T×R ewes but was much less for the R×A cross.

The T×A, T×LR, and R×A crosses showed greatest freedom from neck folds at both ages but they were not significantly different from Targhees except for R×A yearling ewes. The K×R and T×R crosses had significantly more neck folds at both ages than Targhees. The TM-R×LR & K had the most neck folds of any cross studied.

Discussion and Application of Results

Generally when breeds are crossed the offspring show improved merit over the parent breeds. This is usually referred to as hybrid vigor. Experience has shown that when crossbreds are interbred for several generations, as was done in producing the Targhee breed that this hybrid vigor is gradually lost. Therefore, the breed crosses studied here would be expected to excel Targhees in most traits.

The best cross for producing Targhees would then be one that would have greater fleece and body weight, and greater staple length, than Targhees, and type and condition scores equal to or better than Targhees, with open faces and free from folds. No one cross met all of these requirements. The K×R cross was satisfactory except for shorter staple and more neck folds than Targhees. The R×A cross was also satisfactory except for weaning weight, weaning face covering, and type and condition scores at both ages. It should be noted that these two crosses complement each other in that one is strong in the traits in which the other is weak. Gorman *et al.* (1942) comparing Corriedale×Rambouillet and Columbia×Rambouillet yearling ewes found results very similar to those reported here except that in their study Columbia×Rambouillets had heavier fleece weights and much heavier body weights than Corriedale×Rambouillets.

Two of the crosses, T×A and T×LR were equal to or better than Targhees in most traits. These crosses had exceptionally long staple and their fleeces were classified in coarser grades than Targhee fleeces as shown in table 5. Selection for ½ Blood fleeces is emphasized in Targhees.

The cross involving a Tasmanian Merino-Rambouillet ram on Lincoln-

Rambouillet and Columbia ewes was represented by only a few offspring. These were satisfactory for fleece and body weight, staple length and face covering. The number of breeds in this cross may have caused the maximum expression of hybrid vigor for the crosses studied. Their poor type and increased incidence of neck folds would probably limit their usefulness for developing Targhees.

The cross of T×R appeared to be least satisfactory of any of the crosses tried. In this case the crossing of three-quarter Rambouillets on pure Rambouillets probably produced the minimum expression of hybrid vigor of the crosses studied. This cross was inferior to Targhees in every trait at weaning age. Improvement was shown at yearling age in body weight, type and condition although the shorter staple, more covered faces and greater degree of neck folds persisted. The yearling fleeces also graded definitely finer than Targhees. While several generations of top crossing might remove these deficiencies the resulting Targhees would probably be handicapped in comparison with descendants from the other crosses because of the greater selection pressure which would need to be devoted to weaning weight and type, and to staple length, face covering and neck folds at both ages for the T×R cross.

In general the crosses produced offspring which were intermediate in most traits to their parent breeds. Unfortunately strictly comparable information on the parent breeds was not available. The R×A cross gave somewhat higher yearling weights than would have been expected from the parent breeds. Both the K×R and T×R crosses gave a greater degree of neck folds than was expected. In the latter case it was even greater than for straight Rambouillets. It is possible that both the Columbia and Targhee breeds carry recessive genes for folds which are revealed when crossed back to the Rambouillet.

The results presented indicate that both K×R and R×A crosses produce fairly satisfactory Targhees. It is recommended that both crosses be used in producing additional Targhees because they complement each other. Crosses of T×A and T×LR were both satisfactory although their fleeces were not strictly typical of Targhees. Crossing of Targhees on Rambouillets is not recommended because additional generations of crossing would be necessary before typical Targhees could be produced. Also deficiencies in staple length, face covering and neck folds would be difficult to overcome.

Summary

Data on weaning weight, staple length, type, condition, face covering and neck folds were studied on 599 Targhee lambs and 415 breed-cross lambs at the U. S. Sheep Experiment Station, Dubois, Idaho. Also data on yearling

grease fleece weight, staple length, body weight, type, condition, face covering and neck folds were studied on 439 Targhee ewes and 262 breed-cross ewes. In addition, available data from some of these ewes on clean yield, clean fleece weight and commercial grade of fleece were examined. Breed crosses were compared with Targhees to determine their suitability for foundation Targhee breeding.

Columbia × Rambouillet ewes excelled in body weight, type, condition, fleece weight, and open face but were deficient in staple length and freedom from neck folds. Rambouillet × Corriedale ewes excelled in staple length, yearling weight, fleece weight, and freedom from folds, but were deficient in type, condition and face covering. Both of these crosses produced grades of fleeces which were fairly typical of Targhees. These crosses complement each other in that one is strong in the traits in which the other is weak.

Crosses of Targhee rams on Corriedale and Lincoln-Rambouillet ewes produced ewes which were equal to or better than Targhees in most traits. These crosses produced exceptional length of staple but more of their fleeces were classified in coarser grades than were fleeces of Targhees.

The cross of Targhee rams on Rambouillet ewes was least satisfactory for production of Targhees. This cross was inferior to Targhees in every trait at weaning. Yearling body weight, type and condition were better than Targhees, although the shorter staple, more covered faces, and greater degree of neck folds persisted. The yearling fleeces graded definitely finer than Targhees.

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RECORD OF PROCEEDINGS OF THE THIRTY-EIGHTH ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

THE thirty-eighth annual meeting of the American Society of Animal Production was held at the Hotel Sherman in Chicago on November 29 and 30, 1940, and a dinner for the honor guest was held at the Stockyard Inn on December 1. Abstracts of most of the papers presented were published in the November, 1946 issue of the JOUUNAL OF ANIMAL SCIENCE, volume 5, pages 389–423.

PRESIDENT'S ADDRESS[1]

A. D. WEBER

Kansas State College

THIS is the first postwar meeting of the American Society of Animal Production. We rejoice in the opportunity which we again have to renew old acquaintances and to make new friends. We are particularly happy to welcome members who have returned from service with the armed forces. We greet them with a deep sense of pride in their accomplishments and with grateful appreciation for their sacrifices. We are eager to share with them the opportunities and responsibilities in the field of animal husbandry.

Yet it is with mixed feelings that we assemble here. Our joy on this occasion is tempered by the knowledge that some of our members died in the service of their country. Nor can we forget the young men who would have chosen to work in the animal industries had they been spared by the war. They were not members of this Society, but, had they lived, from among their group most surely would have come outstanding leaders. We could ill afford to lose their talents.

This war which took these men from us has given us a new world consciousness. The theme selected for this morning's session reflects the new outlook which members of the Society have gained as a result of war experiences.

It is also sobering to reflect upon the extent to which scientific training, especially in agriculture, was diminished because of World War II. One need not question the policy of deferment that was followed to point out that it resulted in a dearth of well-trained personnel at a time when enrollment in colleges and universities everywhere reached an all-time peak. There is a possibility, too, that academic standards will be lowered, temporarily at

[1] Contribution No. 149, Department of Animal Husbandry, Kansas State College. Delivered Nov. 29, 1946, before the 38th annual meeting of the American Society of Animal Production: Chicago, Ill.

least, in the attempt to find enough teachers to meet minimum requirements.

There is also a danger that in our almost frantic efforts to accommodate staffs and facilities to this sudden onrush of students, we may develop a mass-production complex concerning higher education and forget that tomorrow's progress stems from the training received by the exceptional students of today. In view of the situation that appears to be developing, it would seem that members of the American Society of Animal Production should make a special effort to seek out and encourage young men of exceptional ability. Particularly is it important that encouragement be given to those who have an unusual aptitude for advanced studies in such fields as physiology, animal nutrition, and genetics. More widespread recognition of the basic importance of chemistry, physics, zoology, and mathematics would greatly strengthen graduate study in animal husbandry and related fields.

On the other hand, we must not lose sight of the comparatively large numbers of college students who later will become farmers and ranchers—the solid foundation of the livestock industry. This is important in order that we as research workers and teachers, maintain our close relationship to the industry which we serve.

Despite the importance which may be attached to the training of outstanding young men in the basic sciences, it is unlikely that animal husbandry will ever be transformed from an art to a science. Nor is there any thing to be gained by attempting to resist the impact of the basic sciences upon the art of animal husbandry. Too often misunderstandings and apparent conflicts in the objectives of workers in the several branches of animal husbandry result from a failure to understand the close relationship that exists between the sciences and the art of producing livestock successfully.

In some instances, a better understanding of the place of livestock in our agricultural economy doubtless would help to dispel prejudices and to avoid misunderstandings. Technically trained specialists with a background of practical experience on a livestock farm are more likely to appreciate the importance of animal husbandry as an art than are those who are equally well-trained technically but who have never experienced the thrills along with the disappointments which inevitably come to those who live and work on a stock farm. It is the so-called practical animal husbandman without technical training and the animal scientist without practical experience who are likely to find it difficult to meet on common ground.

One of the important functions of the American Society of Animal Production is to provide an opportunity for individuals having different backgrounds as well as varied interests and training to become familiar with each

other's problems. There is a great need for sympathetic understanding and tolerance when common objectives for research workers, teachers, and extension specialists are being defined. All groups must understand that modern animal husbandry is not an art which is sufficient unto itself but rather an art whose progressive development is dependent upon the practical application of new truths derived from many sciences.

The concept of animal husbandry being dependent upon technical research is not new. In 1908 cognizance of this relationship was taken by the founders of this organization when they named it the American Society of Animal Nutrition. They further recognized its significance by electing an outstanding scientist, Dr. H. P. Armsby, as the first president.

To broaden the base of the Society's activities so as to include all sciences with which animal husbandry is associated, the name was changed in 1912 to the American Society of Animal Production. Since that time every member, irrespective of his field of specialization could have a part in the work of the Society if he desired to take advantage of that privilege. The constantly increasing participation of members in the affairs and programs of the Society has helped significantly to give everyone a broader view of animal husbandry problems. In that connection it has been particularly gratifying to note the response which was made to the call for volunteer papers to be presented at this meeting.

Meetings of the Society have grown from one general session at which a few papers were read and discussed to a listing of 13 sessions and 109 papers in this year's program. Time is not available now for discussions. It has been necessary in recent years to read a considerable number of papers by title only. With research constantly expanding, it is doubtful that the peak has yet been reached.

The executive committee took cognizance of this situation two years ago and instructed the president to appoint a special committee to study the problem and to make recommendations to the Society at the next annual business meeting. It is a matter that deserves thoughtful consideration on the part of the entire membership. Perhaps greater participation in the Society's regional programs would help and the regional programs might well be coordinated in some manner with our national program.

Officers of the Society were confronted with numerous problems during the war. Each year it was necessary to decide whether a meeting would be held. Fortunately, it was possible to schedule a meeting each year except in 1945. Special emphasis was given in these meetings to activities and procedures which had a direct bearing upon the war effort.

Dr. W. V. Lambert who was elected Secretary-Treasurer at the 1943

meeting found it necessary to resign owing to the increased responsibilities of a new position. Fortunately, we were able to persuade Dr. W. G. Kammlade to fill out Doctor Lambert's unexpired term.

The Society has been actively represented on the Inter-Association Council. Other organizations represented on this Council include the American Veterinary Medical Association, Poultry Science Association, United States Livestock Sanitary Association, and the American Dairy Science Association. There are many problems which can be dealt with most effectively through the concerted action of the organizations represented in the Inter-Association Council. Dr. W. V. Lambert, our representative on the Council, deserves special commendation for the time and attention he has given to this work.

Mention also should be made here of the Executive Committee's reappointment of H. W. Marston as the resepsentative of the American Society of Animal Production in the Division of Biology and Agriculture of the National Research Council.

The fact that the JOURNAL OF ANIMAL SCIENCE was published regularly during the War was an inspiration to members of the Society in that trying period. Not only did each issue appear on schedule but there was a noticeable improvement in the quality of the papers published. Dr. Ralph W. Phillips is to be complimented for his splendid work in editing the JOURNAL OF ANIMAL SCIENCE. Praise also is due Dr. R. G. Schott for the capable manner with which he handled this assignment in Doctor Phillips' absence.

There is no gainsaying that the JOURNAL OF ANIMAL SCIENCE has added greatly to the prestige of the American Society of Animal Production among scientists all over the world. Occasionally, however, a member of the Society criticizes the JOURNAL for being too technical. It may be noted that an attempt is now being made to write summaries and conclusions in terms understandable to those who are not specialists in the particular fields covered by the papers. A wide variety of subjects has been covered in the JOURNAL since its first appearance in 1942. It is to be hoped that even a wider range of material will be submitted in the future. After all, the papers which appear in the JOURNAL represent the interest and activity of the membership and not those of the editor and the editorial board.

Consideration has been given to the desirability of preparing popular abstracts of papers published in the JOURNAL OF ANIMAL SCIENCE and making them available to the agricultural press through the Society's special committee on Information. After careful study, it was decided that such a policy would be unwise. If popular releases are to be made it is believed that they should come from the author's institution and be published in the agricultural press, not in the JOURNAL OF ANIMAL SCIENCE.

The Society is particularly fortunate in having R. C. Pollock, General Manager of the National Livestock and Meat Board, as chairman of its special committee on Information. Each year Mr. Pollock's committee abstracts papers presented at the annual meetings and makes available mimeographed releases to over 100 farm papers. A summary of the 1944 report of the Committee on Information shows that in 10 months after the 1944 meeting, 189 articles were used in 59 different publications of 18 states with a combined circulation of 5,231,932. We are indebted to Mr. Pollock not only for a splendid job of reporting but also for assuming the entire responsibility of financing this project.

It is also my privilege and pleasure to acknowledge publicly our appreciation and sincere thanks for the generous gift of Prof. and Mrs. F. B. Morrison for five annual awards of $1,000 each to be given to members of the Society in recognition of their outstanding research accomplishments.

Finally, as a result of serving the Society in an official capacity for six years, I have been personally impressed with the way all of you have cooperated during the trying years of the war. I appreciate your help and want you to know that I feel highly honored by the recognition you have given me.

SUMMARY OF THE MINUTES OF THE THIRTY-EIGHTH ANNUAL BUSINESS MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

W. G. KAMMLADE, *Secretary*
University of Illinois

THE meeting was called to order by President A. D. Weber at 2:30 P.M., November 30, 1946, at the Hotel Sherman, Chicago. One hundred and six members were present.

The Treasurer's report showed total receipts of $10,743.14 which included the balance of $5,002.70 on hand November 1, 1945. Expenditures of $3,977.18 left a cash balance of $6,765.96 on October 31, 1946. Current value of War Bonds brought the total assets, exclusive of The Morrison Award fund, to $8,836.86. An auditing committee of H. R. Guilbert and W. P. Garrigus reported the financial record in order.

The Secretary reported 452 registered in attendance at the meeting. His report showed there were 694 members in 1946; 648 in the United States and 46 in foreign countries. The JOURNAL OF ANIMAL SCIENCE was being sent to 1,053 members and subscribers. All remaining back numbers are stored in the Secretary's office. The Secretary's report contained the suggestion that the Society consider the establishment of a permanent office to handle subscriptions and business matters of the JOURNAL OF ANIMAL SCIENCE.

The Nominating Committee's report was accepted, and officers elected for 1947 as follows: W. A. Craft, *President;* Paul Gerlaugh, *Vice President;* and, W. G. Kammlade, *Secretary-Treasurer.*

It was announced that the new officers for the Western Section are: *President,* F. S. Hultz, Wyoming; *Vice President,* E. B. Stanley, Arizona; and, *Secretary,* R. F. Miller, California. The next meeting of that section will be held at Davis, California, on June 17, 1947.

The North Atlantic Section plans to meet in September, 1947.

The Southern Section did not meet in 1945 or 1946 but plans to meet in February, 1947.

The recommendation of the committee on the Evaluation of Feeds that the committee be discontinued was adopted. Dr. Burch Schneider mentioned the forthcoming publication of a volume of data from 22,000 digestion trials and other material.

The report of the Committee on Information showed much activity by this committee. It prepared material regarding The Morrison Award and also material for the press regarding papers presented at the meeting of the Society. This material was well received by the press, and the Society was thereby given much worthwhile publicity. Mr. H. H. Biggar who gave the report was applauded vigorously.

The Committee on Instruction made no recommendations but mentioned that the program for the Teaching Section on "The Use of Audio-Visual Aids and Other Departures from Conventional Academic Techniques in Teaching" was popular and the papers and discussions well received. The attendance at the meeting was more than 125.

The Committee on Extension made no report but stated that 65 attended the Extension meeting and that several matters were under consideration and recommended the committee be continued.

The Committee on Membership made no special report, but the number of members indicates the efforts to increase the membership were successful.

The Special Committee on Cooperative Meat Investigations reported that it had been largely concerned with the preparation of a program for the Meats Session. While recommendations on meat research programs have been made in the past, the Committee believes that this is being capably handled by the National Committee on Cooperative Meat Investigations. Therefore it recommended that the Special Meat Investigations Committee of the Society be dissolved and that the Meats Session program be arranged by a program chairman appointed by the Executive Committee. An alternative would be to change the name of this committee to Meats Program Committee. A number of suggestions were made on a Meats Session program

for the 1947 meetings. It was generally agreed that a symposium on Factors Affecting the Keeping Quality of Meats would be timely and interesting, the committee reported.

The committee to study the program for the annual meetings reported as follows:

It is recommended: That the sectional programs be based principally upon the general classification: Animal Nutrition, Animal Breeding and Genetics, Animal Physiology, Extension, and Teaching.

That sectional programs be scheduled probably as follows: Animal Nutrition on Friday afternoon, Friday evening, and Saturday morning; Animal Breeding and Genetics and also Animal Physiology on Friday afternoon and Saturday morning; Extension and also Teaching on Friday evening.

It is recognized that some flexibility in programs and in schedules may be necessary. Therefore, it is recommended further, that the Executive Committee of the Society be empowered to make modifications, and to make provisions for a sectional program on Livestock Management and Economics and/or for symposiums upon special subjects as considered advisable.

It is recommended that committees of three members each be appointed to arrange in conjunction with the Secretary, the programs in Animal Nutrition, Animal Breeding and Genetics, and Animal Physiology, and that the sectional programs under this classification be scheduled by the Secretary to avoid as far as possible, conflicts of interest.

Further, that chairmen or special committees, as the Executive Committee deems advisable, be charged with the responsibility for arranging programs in Extension and in Teaching, and in other subjects as needed.

It is recommended also, that chairmen of sectional programs be directed to arrange a definite time schedule for their respective programs and adhere to it; that authors be warned against using slides or other illustrative material excessively and against putting so much on one slide that it is not visible. Further, that chairmen of special or invitational programs develop programs which avoid generalization as much as possible.

For the time being, the Committee believes that new sections are neither necessary nor desirable except as made possible under the first recommendation.

It is the sense of the Committee that it is not advisable to attempt to hold joint meetings of the Society and other groups at present. The Committee recommends, however, that speakers be arranged for from other groups such as Veterinarians, the National Research Council, the American Medical Association, or others as seems desirable. This could be arranged for as a part of the opening session, for the Saturday noon program, or as a part of a symposium.

The Committee recommends that the Executive Committee of the Society and the editorial committee of the JOURNAL OF ANIMAL SCIENCE give consideration to the possibility of publishing in the JOURNAL, abstracts of papers presented at Regional meetings.

The Committee recognizes the fact that Chicago as a meeting place for the Society has advantages and disadvantages. The Committee recommends that a committee be appointed to canvass the membership of the Society on the following:

Whether to continue to hold the meetings of the Society at Chicago or to consider alternative meeting places such as other cities or Land Grant Institutions.

If the Society continues to meet in Chicago, whether it should continue to meet on the present dates or at some other time.

Whether if the time or place of meeting is changed, the meetings should be extended to more than two days.

Such other matters as the Executive Committee may determine,

And further that this Special Committee be directed to report the findings and recommendations to the next regular meeting of the Society for action.

The Special Committee on Pasture and Range Investigations recommended:

That, wherever possible data on the amount of herbage consumed by cattle of different weights and ages be obtained.

That, because of the effect of winter gains and condition upon pasture gains, the condition of cattle at the beginning of pasture trials and their previous treatment, as well as their condition at the close of trials be given in reporting pasture work.

That because of current interest in techniques and procedures for pasture research, a Committee on Pasture and Range Investigations be appointed for the ensuing year with instructions to:

Maintain contact with the pasture committee of the American Society of Agronomy and that of the Dairy Science Association, if any, and

Be prepared to report to the Society at its next regular meeting significant developments in techniques and procedures for pasture and range research.

The Editor of the JOURNAL OF ANIMAL SCIENCE reported:

Two hundred sixty-three manuscripts had been submitted up to November 30, 1946. Of these, 221 were published in Volumes 1 to 5. Eleven were in press for the February, 1947, issue. Eleven were in various stages of editing or were ready for the printer, and 20 had been refused publication or had been withdrawn. In addition to the manuscripts mentioned above, an index of the Proceedings of the Society from 1908 to 1940, inclusive, was prepared by the Editor, and published in the February, 1946, issue, and 92 abstracts of papers to be presented at the 38th annual meeting of the Society were published in the November, 1946, issue. Publication has been kept as nearly up to date as is possible with a quarterly publication, to which the flow of manuscripts is subject to seasonal cycles. For example, when copy for the February, 1947, issue was sent to the printer in mid-November, only one manuscript, upon which editing had been completed, remained in the files.

Dr. W. V. Lambert, the Society's representative on the Inter-Association Council reported:

The successful conclusion of the war largely eliminated the need for quick action on numerous matters with which the Council has been concerned. This change in urgency, together with the fact that several of the member associations have not found it feasible to hold formal meetings, has resulted in the postponement of meetings of the Council.

Your representative is pleased to report, however, that the U. S. Live Stock Sanitary Association reconsidered the Council's program entitled "Promoting and Protecting the Welfare of the Livestock Industry" at their annual meeting in December 1945 and gave it their hearty approval. Thus, the program stands approved by all of the member organizations. At a meeting of the Council, to be held during the summer of 1947, appropriate steps will be taken to activiate those portions of the program which are not currently being handled by other agencies.

It is gratifying to know that as a result of the recognition of the need for vital statistics the Agricultural Research Administration of the U. S. Department of Agriculture, together with several experiment stations, has appointed a committee to give careful consideration to ways and means of obtaining satisfactry vital statistics, including estimates as to their economic importance. These groups were persuaded to undertake the assignment by the Committee on

Veterinary Services for Farm Animals, which is a committee of the Agricultural Board of the National Research Council.

Your representative is also pleased to advise that the Agricultural Board of the National Research Council has favorably received the suggestion that a comprehensive study be executed on the relation of brucellosis to public health. It is expected that a report will be issued in due course.

The programs on animal production, which were developed at the request of the Council and distributed by the National Livestock Conservation Program, are being discontinued in view of the fact that the latter organization is being liquidated.

There has been no changes in the membership of the Council during the past year. The financial condition of the Council remains unchanged, with a bank balance of $386.95. The fund has accumulated as a result of the action of the representatives who have refused to accept payment for operating expenses during the previous two years. In view of the fact that a reserve fund has been established, together with other considerations, the Council did not request additional contributions from the member associations for the year October 1, 1945 to October 1, 1946.

The following resolutions were adopted after being submitted by the Committee on Resolutions:

That thanks be extended to the management of the Sherman Hotel for the facilities, accommodations and courtesies provided under existing circumstances.

That due thanks and appreciation be extended to the officers and committees of the Society for their fine work since our last meeting and to the speakers and guests and all others who have contributed to the various programs of the annual meeting.

That thanks and appreciation be extended to the Committee on Information and to the National Livestock and Meat Board for the excellent services rendered by Mr. Biggar.

Recognition of a long felt need for increased cooperative effort among the State Experiment Stations themselves and with the Federal Government is evidenced by the recent passage of public law No. 733. Such cooperative effort will require coordination which will be most effective if built on thorough confidence in each other among all concerned. It is the sense of the American Society of Animal Production that this can be best accomplished by the development of future research facilities in close association with already established institutions of learning and the State Agricultural Experiment Stations.

Since there is a widespread confusion and definite lack of information regarding the relation of size and other characters to efficient production and carcass return in beef cattle, it is the sense of the American Society of Animal Production that further thorough-going investigations be instituted to establish the facts regarding the factors responsible for the most efficient production. Such an investigation may well become part of any cooperative beef cattle breeding program. As data are obtained, conferences may be advisable to establish indices through which progress can be definitely recorded.

The American Society of Animal Production commends the Program Committee for the review of world livestock affairs at this meeting. Continuous attention to this important subject is necessary in order to develop sound thinking on the importance of the livestock industry to agricultural economy and human welfare the world over, and also the necessary limitations on the widely advocated thesis that all grains should be withdrawn from animal production in the attempt to meet the world human food crisis.

The Committee on Necrology presented memorials for two deceased members, which are reproduced immediately following this report.

MEMORIALS

FRANKLIN GEORGE KING

Franklin George King died at Lafayette, Indiana, September 5, 1946, at the age of 61 years after a long period of failing health. Professor King's entire life was spent in the atmosphere of livestock production. He was born and reared on a livestock farm near Sweet Springs, Missouri, and educated for his life's work at the University of Missouri, from which he was graduated in 1907. After graduation, he spent a year in the employ of his alma mater assisting Dean H. J. Waters with the famous growth studies which were then in progress at the Missouri Agricultural Experiment Station. Following this he was employed for a year by the Kansas State Board of Agriculture to do livestock extension work, from which position he went to the staff of the Kansas State College. After a year at that institution, Purdue University convinced Professor King that his opportunity for service was to be found in Indiana. This proved to be true, and the remaining 36 years of his life Professor King spent in devoted service to Purdue University and the livestock industry of the state, except for about two years spent in the Field Artillery (325th) during World War I.

Professor King's early years at Purdue were devoted entirely to research in livestock feeding, a field which expanded greatly under his direction. In October, 1928, he was made head of the Department of Animal Husbandry. In this position Professor King continued active supervision of the experimental beef cattle feeding work and gave effective leadership to the development and the breeding and management of the flocks and herds of Purdue University. He was a hard worker and a positive character. His council was sought by students, stockmen, and civic leaders alike.

F. B. MUMFORD

Dean emeritus F. B. Mumford of the College of Agriculture, University of Missouri died November 12, 1946, from injuries sustained in an automobile accident October 14 which took the life of his wife. Dr. Mumford was born in Moscow, Michigan, May 28, 1868 and received his higher education at Albion College, Michigan State Agricultural College, the University of Leipzig, and the University of Zurich. He was the recipient of honorary degrees from the University of Nebraska and Michigan State College.

After four years of service on the staff of Michigan State College he joined the staff of the College of Agriculture, University of Missouri, in 1895 and continued there until the time of his retirement in 1938. He served the Missouri College of Agriculture effectively in various capacities from young assistant in Animal Husbandry to Dean and Director. But his influence reached beyond his own college and university, even beyond his own state to the cause of agriculture throughout the land. In 1928 he was selected with his brother, H. W. Mumford, then Dean, College of Agriculture, University of Illinois, as honor guest of the Society.

CHAIRMEN OF COMMITTEES AND SECTIONAL MEETINGS FOR 1947

The chairmen of standing and special committees appointed for the year 1947 are as follows:

Committee on Investigation.....J. K. Loosli (New York)
Committee on Instruction.....E. H. Hughes (California)
Committee on Extension.....L. K. Bear (Ohio)
Committee on Membership.....Paul Gerlaugh (Ohio)
Special Committee on Information.R. C. Pollock (Nat'l Livestock and Meat Board, Chicago)
Special Meats Committee.....D. E. Brady (North Carolina)
Special Committee on Pasture and Range Investigations.....M. L. Baker (Nebraska)
Special Committee on Necrology.....W. E. Carroll (Illinois)
Special Committee on Program.....M. L. Baker (Nebraska)
Special Committee on History of Livestock..E. N. Wentworth (Armour and Co., Chicago)
Special Committee on Time and Place of Meeting.....H. R. Guilbert (California)
Morrison Award Committee.....Paul Gerlaugh (Ohio)
Representative on Inter-Association Council.....E. A. Livesay (W. Va.)
Representative on National Research Council's Division of Biology and Agriculture.....
.....H. W. Marston (U.S.D.A.)
Representative on American Association for Advancement of Science.....
.....E. C. Elting (U.S.D.A.)

The chairmen of sectional programs for the thirty-ninth annual meeting to be held in 1947, will be as follows:

Animal Breeding and Genetics.....J. L. Lush (Iowa)
Animal Nutrition.....T. S. Hamilton (Illinois)
Animal Physiology.....F. N. Andrews (Indiana)
Extension.....L. K. Bear (Ohio)
Teaching.....E. H. Hughes (California)

It is possible that other sections will be included in the 1947 program. This will be determined as work on the program progresses, and any additional sections, together with chairmen, will be announced at a later date.

HENRY P. RUSK

Honor Guest—1946

Henry Perly Rusk is an outstanding leader of American Agriculture. As Dean of the University of Illinois Agricultural College, as a member of the Agricultural Board of the National Research Council, as a trustee of the Farm Foundation, and as member or advisor of many other organizations he has helped establish policies and programs of national scope and importance. He was president of the American Society of Animal Production in 1925–26, and has held other offices and appointments in organizations of state and national significance.

He was born on a farm near Rantoul, Illinois, July 19, 1884, was educated in Indiana and Missouri to which states his parents moved, and received the degree of Bachelor of Science from Valparaiso University in 1904 and the degrees of Bachelor of Science and Master of Science from the University of Missouri in 1908 and 1911 respectively. He was a member of the first collegiate judging team to represent Missouri at the International Live Stock Exposition, and was one of the founders of Farm House national agricultural fraternity. He served for one year as an undergraduate assistant in Animal Husbandry at the University of Missouri, was on the staff at Purdue University for one year, and came to Illinois in 1910, where he assumed charge of the Beef Cattle Division and taught courses in beef production and carried on extensive cattle-feeding experiments. In 1922 he was appointed head of the Animal Husbandry Department and in 1939 became Dean of the College of Agriculture, Director of the Experiment Station, and Director of the Extension Service in Agriculture and Home Economics.

Most of Dean Rusk's research was concerned with practical problems, but he was associated in many projects covering a wide range of technical subjects. He aided in solving forage poisoning (botulism) in cattle and horses, and helped in conducting digestion trials and metabolism studies. Pasture research occupied his attention for many years as did methods of storing and utilizing the corn crop. His unusual ability to appraise the relative importance of various problems and his competence in evaluating procedures have been important administrative contributions to research. He has shown a keen sense of fitness in problems of departmental and institutional relationships.

HENRY P. RUSK

Reproduction of a portrait presented to the Saddle and Sirloin Club in Chicago by the American Society of Animal Production on December 1, 1946. Henry P. Rusk was the Honor Guest of the Society during its annual meeting which was being held at that time.

THE MORRISON AWARD

1946

The Award Committee of the American Society of Animal Production has selected, from the list of nominees submitted, Dr. Jay L. Lush of Iowa State College to receive the Morrison Award for 1946. The selection was based on Dr. Lush's research relating to: methods of interpretation of experimental results including breeding, feeding and carcass data; changes in conformation due to the fattening process in cattle; proving sires and developing selection indexes; inbreeding and genetic history of livestock; measures of productivity of sows; inheritance of various characters in swine; crossbreeding swine; inbreeding and the development of inbred lines of swine; systems of breeding; consequences of selection combined with inbreeding; and his contribution to animal husbandry through his book "Animal Breeding Plans."

Dr. Lush received his B.S. and M.S. degrees from Kansas State College in 1916 and 1918, respectively, and the Ph.D. degree from the University of Wisconsin in 1922. He was an assistant in Genetics at Wisconsin from 1919 tc 1921, Animal Husbandman at the Texas Agricultural Experiment Station from 1921 to 1930, and Professor of Animal Breeding at Iowa State College since 1930. He served the American Society of Animal Production as Secretary from 1935 through 1937, as Vice-President in 1938 and as President in 1939.

Jay L. Lush

Jay L. Lush was awarded the first Morrison Award, which was presented to him during the Thirty-Eighth Annual Meeting of the American Society of Animal Production, in Chicago, on November 30, 1946.

NEWS AND NOTES

Ralph W. Phillips, formerly in charge of Genetics Investigations in the Bureau of Animal Industry, is now with the Food and Agriculture Organization of the United Nations where he is in charge of animal industry work in the Agriculture Division. He will continue as Editor of the JOURNAL OF ANIMAL SCIENCE, and all correspondence concerning manuscripts and other JOURNAL matters should be addressed to him as follows:

Dr. Ralph W. Phillips
Editor, JOURNAL OF ANIMAL SCIENCE
Food and Agriculture Organization of the United Nations
2000 Massachusetts Avenue, N. W.
Washington 6, D. C.

A book entitled "The Problem of Fertility" has recently been issued by the Princeton University Press, Princeton, New Jersey. It is edited by Earl T. Engle, and contains the following chapters by members of the American Society of Animal Production: Patterns of Estrous Cycles, by S. A. Asdell; Ovulation and Estrus in Sheep and Goats, by R. W. Phillips, R. M. Fraps, and A. H. Frank; Induction of Ovulation and Subsequent Fertility in Domestic Animals, by L. E. Casida; The Induction of Ovulation in Domestic Animals, by John Hammond; Hormonal Control of Ovulation, by H. H. Cole; Glycolysis, Livability, and Fertility of Bovine Spermatozoa, by G. W. Salisbury; Biology of Equine Spermatozoa, by Victor R. Berliner; Artificial Insemination of Dairy Cattle, by J. W. Bartlett; The Effect of Synthetic Thyroprotein on Sterility in Bulls, by E. P. Reineke; and Methods for Determining the Time of Ovulation in Domestic Animals, by John Hammond. Other chapters deal with the following subjects: The Ovary at the Time of Ovulation by George W. Corner; Cervical Mucus and the Menstrual Cycle, by W. T. Pommerenke and Ellenmae Viergiver; Spermatozoa and Cervical Mucus, by A. R. Abarbanel; Metabolism and Motility of Human Spermatozoa, by John Macleod; Fertilizing Capacity of Rabbit Spermatozoa, by M. C. Chang; and The Cervix Uteri in Sterile Matings, by Fred A. Simmons. This should be a useful reference volume for all workers who deal with problems of physiology of reproduction.

J. M. Cooper, formerly Assistant Superintendent of the Navajo Agency at Window Rock, Arizona, is now Superintendent of the Wind River Agency at Fort Washakie, Wyoming.

Earle W. Klosterman, who recently received the degree of Doctor of Philosophy (in animal husbandry) at Cornell University, has been appointed assistant professor at South Dakota State College. He will have charge of sheep production and nutrition investigations.

James J. Kiser of Iowa State College recently joined the South Dakota State College staff as an instructor. Mr. Kiser will have charge of the animal husbandry livestock judging teams.

Lloyd S. Crouch, formerly with "The Farmer's Guide," is now with the Western Livestock Journal, 4511 Produce Plaza, Union Stock Yards, Los Angeles 11, California.

S. H. Work, formerly of the Office of Foreign Agricultural Relations, joined the staff of the Office of Experiment Stations on January 12, where he will be principal experiment station administrator in animal husbandry.

Charles L. Blackman, extension dairy husbandman at Ohio State University, is going to Colombia for a year as a member of a mission under the auspices of the Office of Foreign Agricultural Relations in the U.S.D.A. His headquarters will be in Bogata temporarily, but may be at Medellin, Colombia, later on.

W. V. Lambert was made Administrator of the Agricultural Research Administration, U.S.D.A., on November 1, 1946, to succeed P. V. Cardon who, because of his health, voluntarily transferred to the position of special assistant to the Chief, Bureau of Plant Industry, Soils and Agricultural Engineering.

DeVoe Meade, a member of the staff of the animal and dairy husbandry departments of the University of Maryland for 28 years, retired on October 1, 1946.

George Haines, who was in charge of the section on animal genetics, of the Office of Experiment Stations, U.S.D.A., retired on August 23, 1946, after nearly 25 years of continuous service.

E. B. Forbes, who has been head of the Institute of Animal Nutrition at Pennsylvania State College since 1922, retired from active duty on June 30, 1946.

J. W. G. MacEwan, head of the animal husbandry department at the University of Saskatchewan, Saskatoon, for the past 10 years, has been made dean of agriculture and home economics at the University of Manitoba, Winnipeg.

H. H. Kildee was made director of extension, Iowa State College, July 1, 1946. He also is dean of agriculture and director of the experiment station.

Horace T. Strong, a graduate of Oregon State College, was appointed extension specialist in animal husbandry at the University of California, effective October 1, 1946, to succeed S. D. Nelson who transferred to county agent work.

Burl Winchester, formerly on the staff at University of Wisconsin, is now associate professor of animal husbandry at North Dakota State College.

Paul A. Gantt has returned to his former position as extension animal husbandman, University of Hawaii, after nearly five years devoted to wartime emergency assignments in the Pacific area.

Don Chittenden became secretary of the American Polled Hereford Association in December, succeeding B. O. Gammon who retired to an emeritus position with the same organization.

Hubert M. Barnes, former country agricultural agent, succeeded Howard Davison as extension swine specialist at Ohio State University on January 1, 1947.

R. D. French, extension animal husbandman, University of Illinois, resigned November 1, 1946, to take a position with the Farm Bureau insurance department in Champaign County.

R. R. Snapp, professor of beef cattle husbandry, University of Illinois, has returned to regular duty after nearly five years military service, part of which was at Florence and Rome, Italy.

J. R. Sprengle, former county agent in Routt County, Colorado, has been appointed to succeed H. H. Smith as extension animal husbandman on the staff of Colorado State College. Mr. Smith resigned to become director of farm market relations for a food-chain supported agency.

C. L. Hill has returned from extended military service to assume his former duties as extension animal husbandman at Louisiana State University.

Lloyd D. Miller, graduate of the University of Missouri and veteran of World War II, has been made publicity director for the American Aberdeen-Angus Breeders' Association, succeeding DeWitt C. Wing.

Marden Broadbent, former county agent, has been made assistant livestock specialist at the Utah State College.

William J. Beck, former county agent, has been made associate extension livestock specialist at the Oklahoma A. & M. College.

Frank Dillard has been reappointed assistant extension animal husbandman, University of Missouri, following military service.

James W. Linn, former extension dairy husbandman, Kansas State College, has been ap-

pointed extension animal husbandman, New York State College of Agriculture, to serve during the absence of S. J. Brownell who is with A.M.G. in Germany.

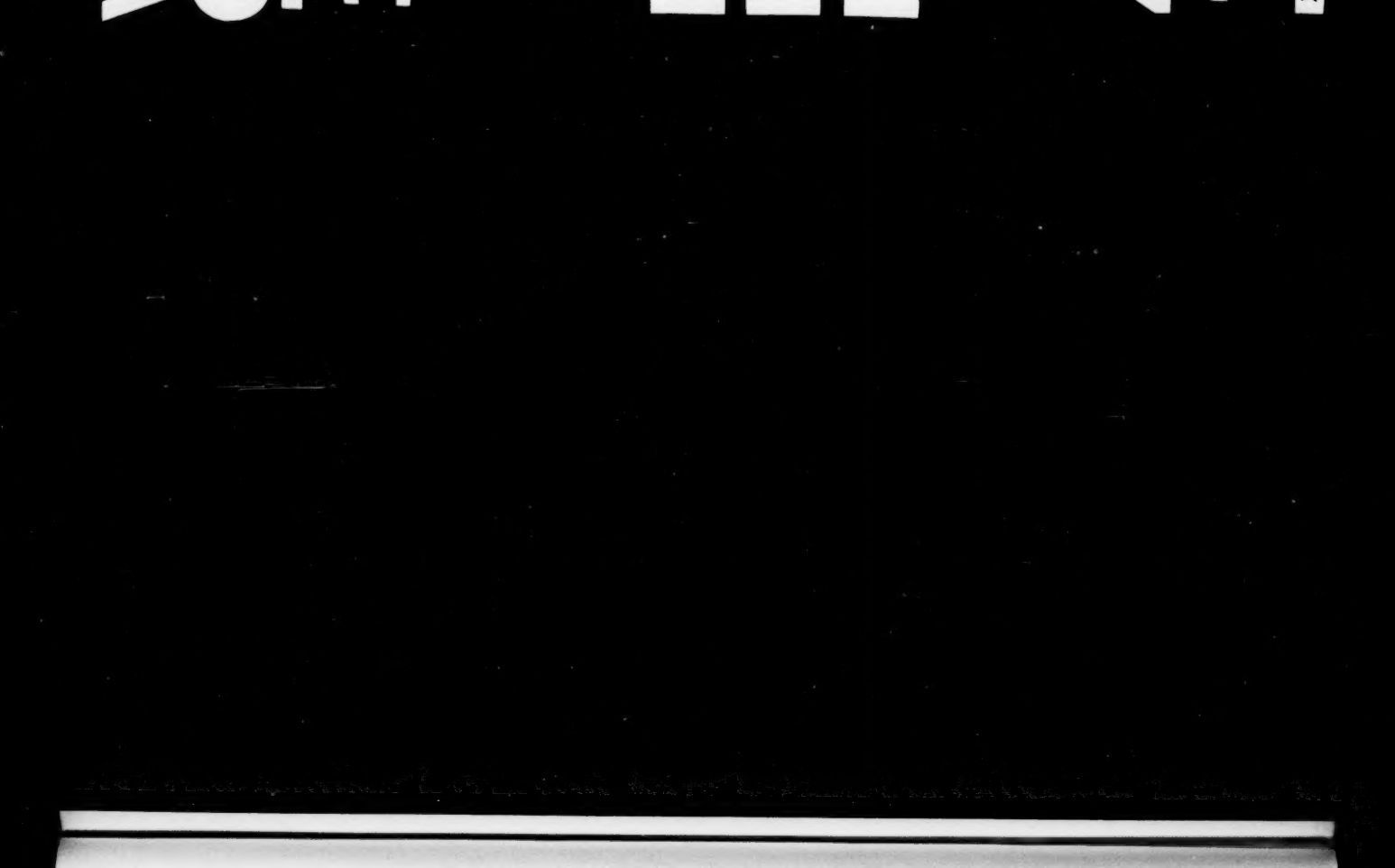
Joe V. Whiteman, former county agent in Colorado and more recently in military service, has been made assistant extension animal husbandman at the New Mexico State College.

Adam J. McWilliams, recently manager of Morlunda Farms and a graduate in animal husbandry, University of Minnesota, has been made eastern field representative of American Hereford Association.

T. E. Hamilton, who has had charge of extension phases of sow testing and swine breeding, University of Wisconsin, has resigned to take up other work.

Chas. R. Kyd, returning from military service, has been reappointed extension animal husbandman at the University of Missouri.

R. W. Pifer, of the animal husbandry staff, University of Kentucky, has resigned to enter commercial work.

Howard M. Stamey, assistant extension animal husbandman, North Carolina State College, has voluntarily transferred to county work in Iredell County in the same State.

James A. McGregor, graduate in animal husbandry, University of Maryland recently discharged from the Army Air Corps where he held the rank of major, has been appointed herdsman in the department of animal husbandry, Washington State College.